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OF THE

IMPERIAL
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COMMITTEE.

Vol. VII. No. 1.

TOKYO. AUGUST, 1914.

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ERRATUM AND ADDITION.

(The Bulletin, Vol. VII, No. 1)

Pl. XVIII, Fig 49. *For* Time Scale: 1 minute = 52 mm,
read Time Scale: 1 minute = 202 mm.

P. 186. To be *added* to the foot-notes (1) and (2): The distances of some of the different observing places from the Asama-yama given in this volume are slightly different from those in the preceding, owing to the correction applied to the latitude and longitude of the mountain adopted in the calculation.

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THE ERUPTIONS AND EARTHQUAKES OF THE ASAMA-YAMA. IV.

[Strong Asama-yama Outbursts, Dec. 1912 to May 1914.]

By

F. OMORI, Sc. D.,

Member of the Imperial Earthquake Investigation Committee.

With Plates I—XXXIV.

CHAPTER I. ACTIVITY OF ASAMA-YAMA IN 1912 AND 1913.

1. *Introduction.* The recent extraordinary volcanic activity of the Asama-yama, which began in 1908, has apparently reached its maximum intensity during the last two years. In 1912, in which there was no violent *explosion* of the mountain, the non-eruptive volcanic earthquakes were very numerous; that of July 16th being especially large and violent. Again, the eruptions on Oct. 2nd and Dec. 13th–14th (Fig. 2), each of which consisted of a great number of outbursts individually not very strong, lasted respectively 8 and 31 hours, and caused remarkable elevations of the crater bottom, which became on the N and NW side practically continuous with the top of the surrounding wall. In 1913, in which the non-eruptive volcanic earthquakes were extremely few, the strong eruptions, both explosive and non-explosive (§ 3), were very numerous; there being in the course of the year, at least 16 outbursts, whose detonations were heard at considerable distances from the volcano. In 1913 there were also remarkable epochs of the continuous volcanic activity. Thus, in July between the 5th, 3½ p.m., and the 6th, 7 p.m., the tromometer at Yuno-taira registered the shakings of some 1,300 small eruptions; while, on Oct. 15th, between 4½ a.m. and 2 p.m., the tremor-recorder at Ashino-taira indicated about 250 of the similar disturbances.

One of the marked features of the eruptions in 1913 was the increase in the distance to which the red hot lava fragments were projected. The four strong explosions of June 17th, July 13th and 19th, and Aug. 12th, sent the projectiles to the immediate vicinity of, and to places beyond, the Yuno-taira seismological observatory, causing damage to the window on the crater side. On Aug. 12th, the "Volcano House", a sort of resting cottage for the mountain climbers situated at Yuno-taira about 250 m nearer the crater which had already been abandoned, fared very badly, its roof being perforated, and its inside partially burnt, by a great number of the falling stones. Such effects of the great violence of the outburst, which did not occur in 1914 so far, neither in the years preceding 1913, might be due in a part to the elevation of the crater bottom, but in the main probably to the change in the depth of the most active under-mountain centre of the volcanic activity; it being likely that there exists a particular focal depth corresponding to the maximum projection intensity of the eruption.

In 1914 the seismological and meteorological observations were carried on at Yuno-taira in the same way as in the preceding year, from May 3rd to Aug. 31st. Then, between Sept. 1st and Oct. 22nd, the tremor-recorder was taken to the temporary station at Ashino-taira, a place about 2640 m below Yuno-taira, where the trial registers had first been taken in the winter of 1911. On

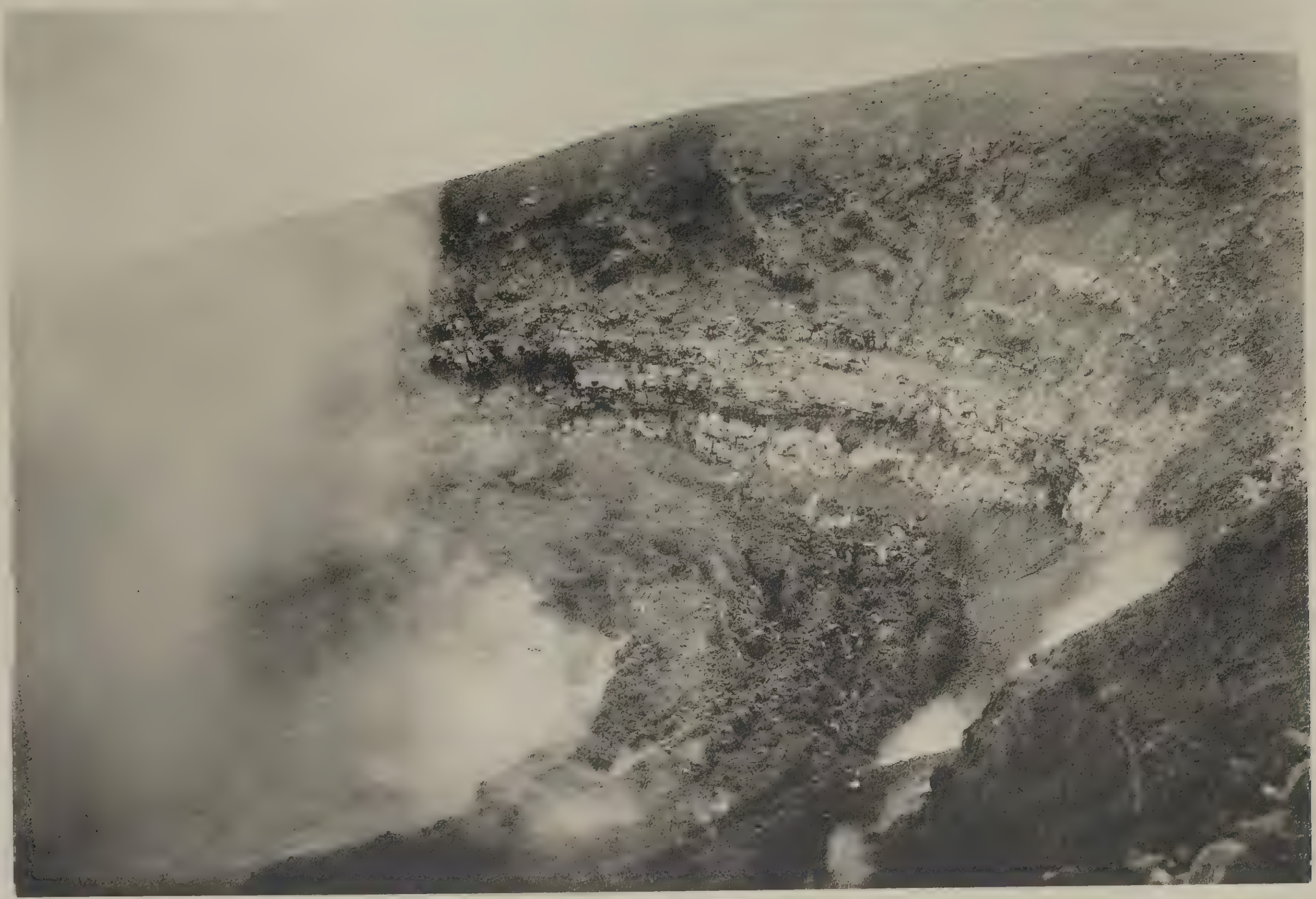

Fig. 1. View of the crater of Asama-yama, from SSW, showing **lava rings** at the bottom. July 2nd, 1912. (F. Omori, phot.).

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Pl. II.

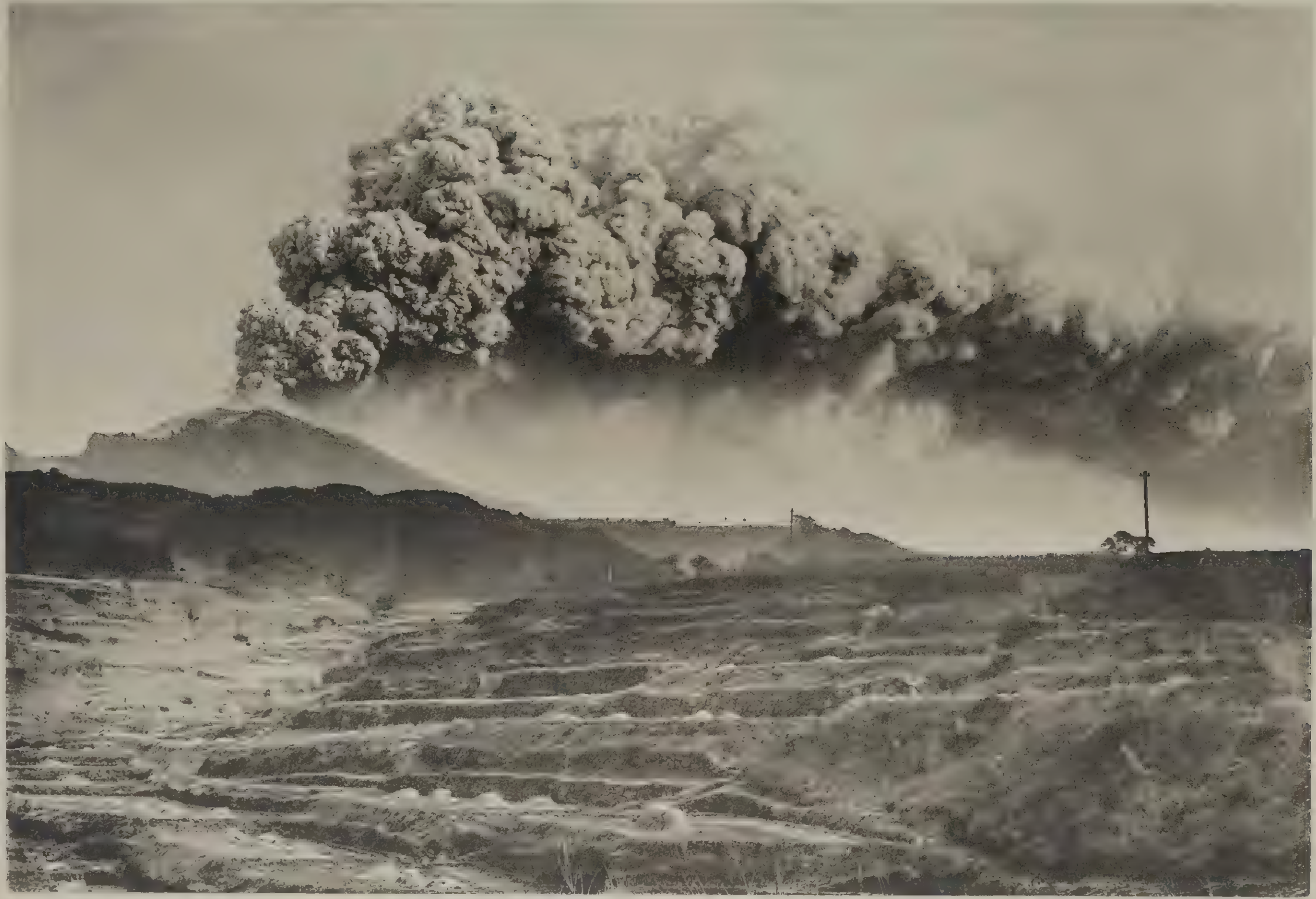

Fig. 2. Eruption of Asama-yama on Dec 14th, 1912, seen from Komoro. (K. Uozu, phot.)

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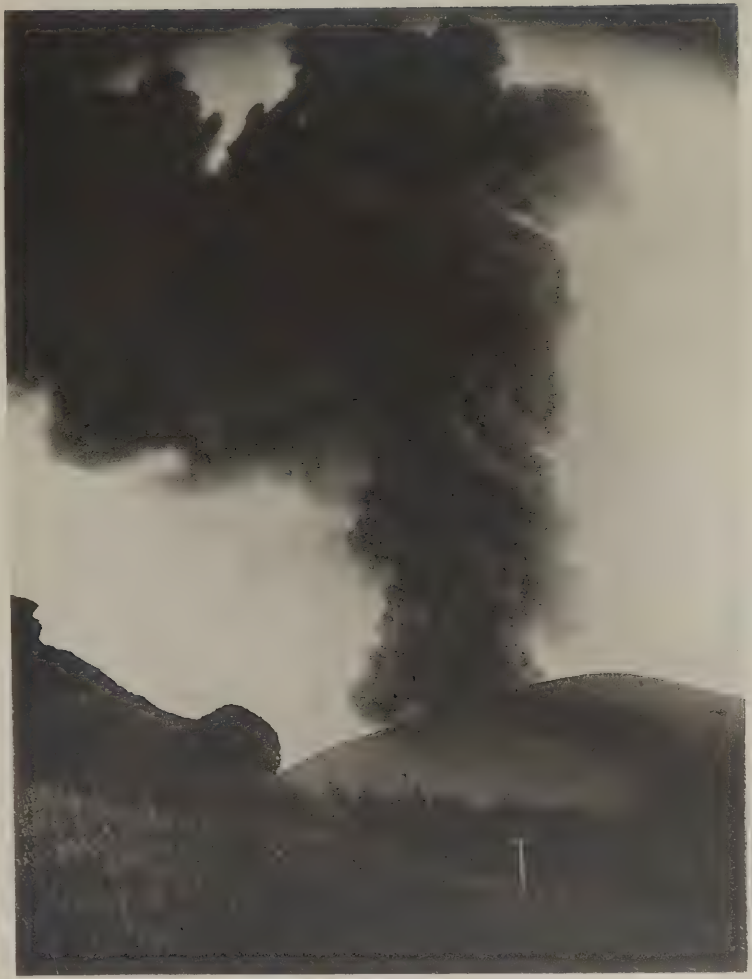

Fig. 3. A small eruption of Asama-yama on July 13th, 1913, at about 7.26 a.m., seen from Yuno-taira. (T. Kato, phot.)

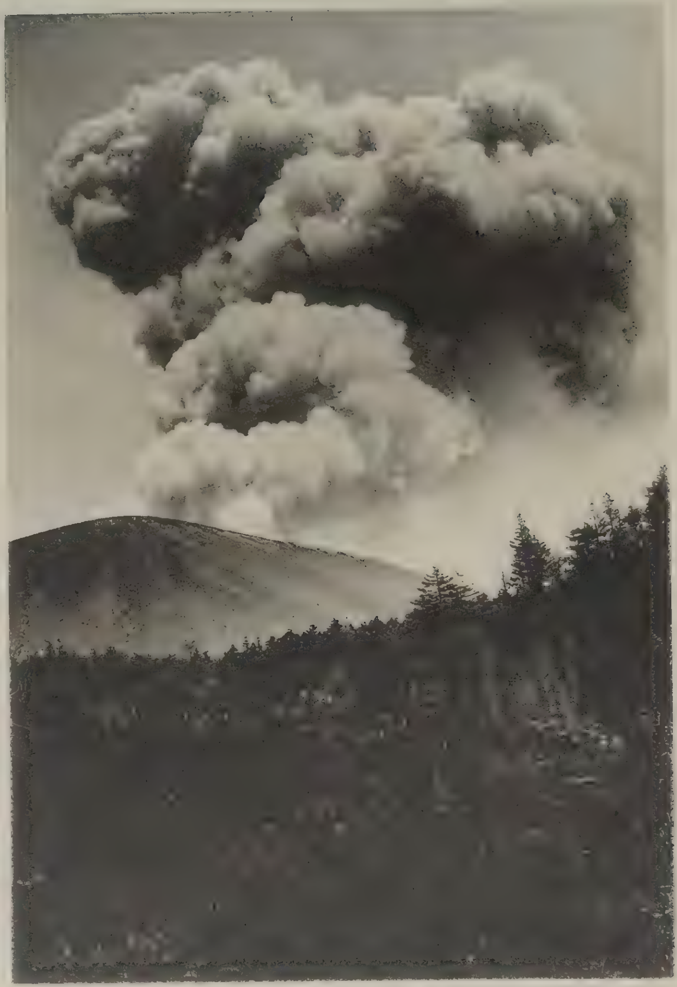

Fig. 4. A strong non-detonative eruption of Asama-yama on July 1st, 1913, at 0.17.01 p.m., seen from Yuno-taira 4 minutes after the commencement. (T. Kato, phot.)

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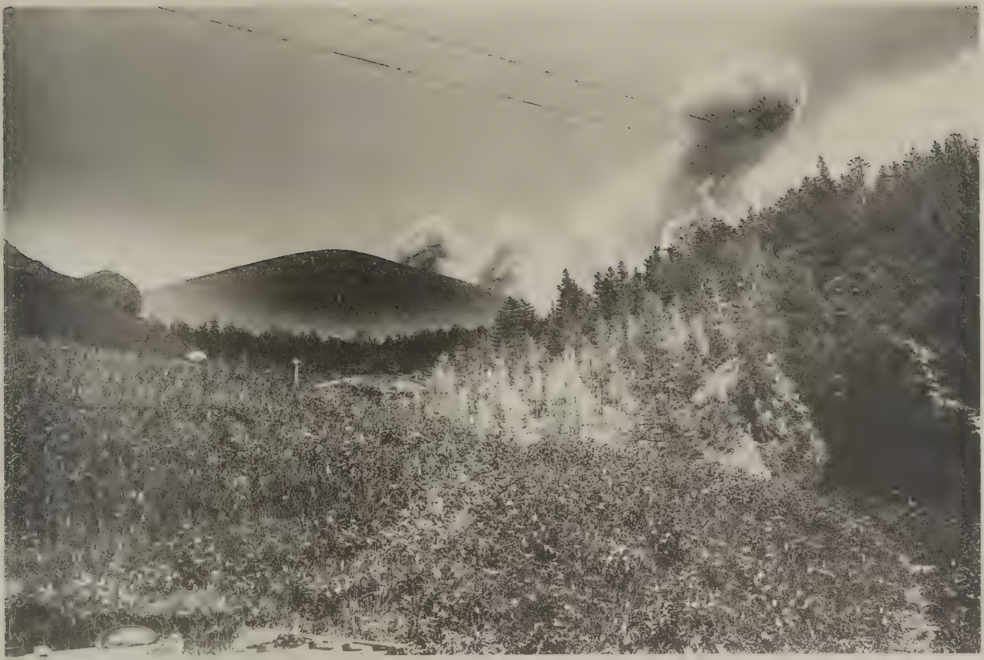

Fig. 5. Maikake-yama seen from Yuno-taira, on July 27th, 1913, at 1 30 p.m. The smoke groups were successively thrown eastwards. (F. Omori, phot.)

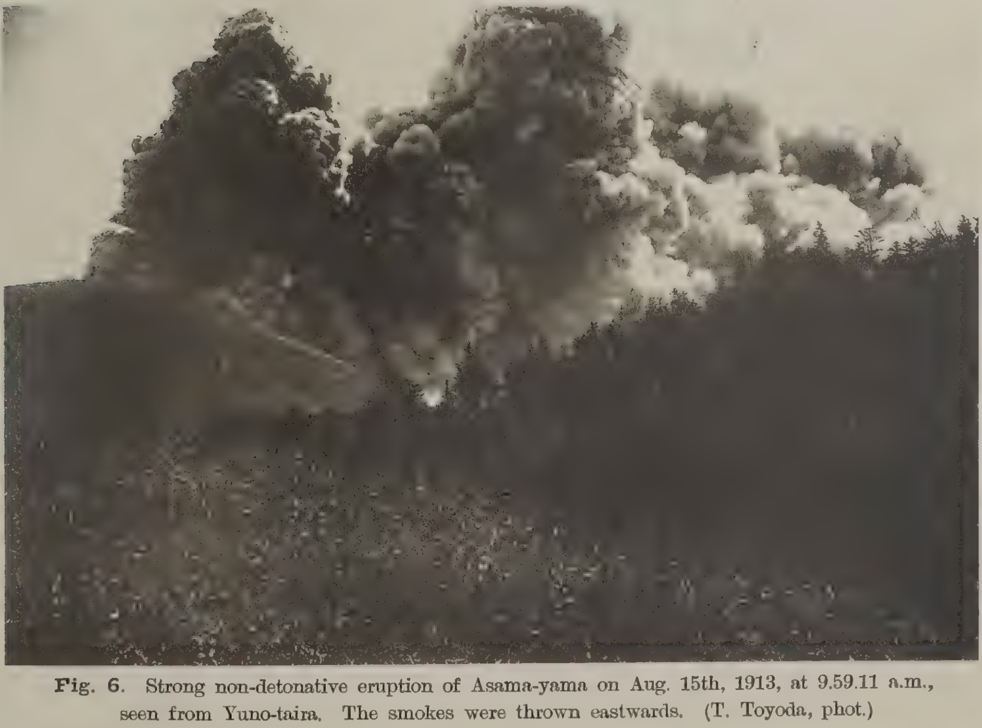

Fig. 6. Strong non-detonative eruption of Asama-yama on Aug. 15th, 1913, at 9.59.11 a.m., seen from Yuno-taira. The smokes were thrown eastwards. (T. Toyoda, phot.)

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the other hand, the observation with another tremor-recorder of 200 times magnification was carried on, from Sept. 11th to Oct. 24th, and again from November 12th to Dec. 6th, in the office building of the Asama Pasture Ground at the distance of about 6350 m to the N 65° E of the Asama-yama crater. (See Fig. 45.)

The present paper is principally devoted to the consideration of the sound phenomena and the earthquake effects of the different strong eruptions in 1913, and those of Dec. 13th–14th, 1912, and May 5th, 1914; the full description of the diagrams of the non-eruptive volcanic earthquakes, the discussion of the areas of the seismic propagation, and other matters, being reserved for a future number of the *Bulletin.*

2. *List of Asama-yama eruptions in* 1912 *and* 1913. Table I is the continuation of a similar list for 1908–1911 (Table V, the *Bulletin*, Vol. VI, No. 1) and gives the date and time of occurrence of the 46 eruptions of the Asama-yama, which occurred in the course of the two years, 1912 and 1913, and whose detonation or emission of ashes was intense enough to be noticed in the neighbouring or distant provinces, or at least in places outside the immediate base of the mountain.

TABLE I. LIST OF THE ASAMA-YAMA ERUPTIONS, 1912—1913.

(**) ....Eruption of a long duration.
(*) ....Strong Eruption.

No.[1]	Date.	Time of Occurrence (at Asama-yama).	Remarks.
63	Jan. 28, 1912.	6.36 a.m. to 7.25 p.m.	Detonations heard at Naganohara and Maebashi. Ashes fell at Karuizawa and vicinity, and also at Kumagai and other places in Saitama Prefecture.
64	Feb. 13–14, ,,	10 p.m. (13th) to 7 a.m. (14th).	Ashes fell at Komoro and Kumagai.

[1] The number is counted in continuation of Table V, the *Bulletin*, Vol. VI, p. 25.

No.	Date.	Time of Occurrence (at Asama-yama).	Remarks.
65	Feb. 22, 1912.	7.20 and 10.50 p.m.	Detonations heard at Naganohara.
66	April 9, ,,	0.35 p.m.	Detonation heard at Naganohara.
67	,, 15, ,,	7.50 p.m.	Dull detonations heard at Naganohara.
68**	Oct. 2, ,,	10 a.m. to 7.40 p.m.	Detonations heard at Naganohara and Maebashi, with ash-precipitation at the former.
69	,, 3–4, ,,	8.40 p.m. (3rd) to 10 a.m. (4th).	Dull detonations heard at Naganohara.
70	,, 7, ,,	2 a.m.	Detonations heard at Karuizawa, with slight ash-precipitation at Kumagai.
71	,, 9–10, ,,	$9\frac{1}{2}$ p.m. (9th) to $2\frac{1}{3}$ a.m. (10th).	Loud detonations heard at Naganohara.
72**	Dec. 13–14, ,,	Lasted 31 hours.	Ashes were carried ENE'ward to the Pacific coast. The detonations were perceived in the provinces of Kotsuke, Shimotsuke, Hitachi, Musashi, Shimosa, Sagami, Izu, Suruga, Totomi, Shinano, Iwaki, and Iwashiro.
73	Feb. 11, 1913.	2. 15. 40 p.m.	Detonation heard at Nagano, Maebashi, and Kumagai and other places in Saitama Prefecture.
74	April 18, ,,	11. 53. 50 p.m.	Detonation heard at Maebashi.
75	,, 21–23, ,,	Several outbursts.	Detonation and ash-precipitation at Naganohara and Maebashi.
76*	May 16, ,,	4. 41. 00 p.m.	Detonation heard at Naganohara, Maebashi, and Kumagai and other places in Saitama Prefecture.
77*	,, 27, ,,	5. 22. 57 a.m.	Loud detonation heard at Naganohara, Kusatsu, Komoro, and Karuizawa.
78*	,, 29, ,,	10. 44. 12 a.m.	Detonation heard at Komoro, Naganohara, Maebashi, Kumagai and other places in Saitama Prefecture; also at different localities in Totomi, Suruga, Mikawa, Owari, and Mino. Ash-precipitation at Naganohara and a few places in central Echigo.
79	June 13, ,,	11. 01. 16 p.m.	Loud detonation heard at Naganohara.
80*	,, 17, ,,	10. 47. 41 p.m.	A strong explosion, whose detonation was heard on the one hand in provinces of Shinano, Echigo, Kotsuke, Shimotsuke, Musashi, Shimosa and Hitachi; and on the other hand, in Noto, Etchu, Kaga, Echizen, Omi, Mino, Owari, Mikawa, Totomi, and Suruga. Ash-precipitation zone extended eastwards to the Pacific coast.
81	,, 18, ,,	6. 21. 03 a.m.	Detonation heard at Naganohara.

No.	Date.			Time of Occurrence (at Asama-yama).				Remarks.
82*	June	20,	1913.	4h	06m	47s	a.m.	Detonation heard in Kotsuke and a few places in the neighbouring provinces, the ash-precipitation zone extending toward ESE for about 90 km. The W. sound area stretched from Noto to Owari.
83	,,	24,	,,	11	37	34	a.m.	Sound heard at Naganohara?, ashes falling for 5 min. at 9.10 a.m.
84*	,,	26,	,,	8	09	40	a.m.	Detonation heard in Kotsuke and at a few places in Echigo and Shinano, the ash-precipitation zone stretching eastwards only to Maebashi. The W. sound area included parts of Mino, Owari, and Mikawa.
85*	,,	,,	,,	11	41	59	p.m.	The sound areas were similar to those of the preceding. There was ash-precipitation at Maebashi.
86	July	1,	,,	0	17	01	p.m.	At Wakasare, there was some ash-precipitation.
87	,,	7,	,,	7	10	32	a.m.	Detonation heard at Naganohara, Maebashi, and a few other places in province of Kotsuke.
88	,,	,,	,,	9	46	53	p.m.	Loud detonation heard at Naganohara.
89	,,	8,	,,	5	25	25	a.m.	*Do.*
90*	,,	13,	,,	4	01	19	p.m.	The principal sound area stretched in the S W from Suruga to Omi; the detonation being heard, on the other hand, only within a very limited distance of the volcano. Ashes fell at Naganohara.
91*	,,	18,	,,	2	08	34	a.m.	Loud detonation heard at Naganohara. The sound was also perceived toward the west at Kanazawa (Kaga), and at Gifu, Mitake, and Shiratori (Mino).
92*	,,	19,	,,	0	54	03	p.m.	The sound area consisted of 3 isolated portions the largest of which extended from Totomi to Omi.
93*	Aug.	12,	,,	7	45	08	p.m.	Detonation heard at Karuizawa, Iwamrata, and Komoro, in Shinano; at Naganohara; and a few places in Mikawa, Owari, and Kaga.
94*	,,	,,	,,	11	20	33	p.m.	A strong explosion, whose sound area consisted of 3 portions similar to, but greater than, those in the preceding case. The ash-precipitation zone extended to Mount Tsukuba toward the E slightly S.
95	,,	15	,,	9	59	11	a.m.	Powerful smoke emission, unattended by detonation.

No.	Date.	Time of Occurrence (at Asama-yama).	Remarks.
95′	Aug. 15, 1913.	3h 58m 46s p.m.	Powerful smoke emission, unattended by detonation.
95″	,, ,, ,,	5 08 54 p.m.	*Do.*
96*	Sept. 21, ,,	1 50 59 p.m.	The sound area, composed of 2 separate portions, was similar to those of the explosions on July 13th and June 26th, at 8 a.m.
97*	Oct. 15, ,,	10 43 13 p.m.	Detonation heard at Nagano and Iwamrata in Shinano, and Maebashi and Sannokra in Kotsuke.
98*	,, 17, ,,	3 27 47 p.m.	Detonation heard at Maebashi, Sannokra, Naganohara, and Kusatsu, in Kotsuke.
99*	,, 26, ,,	3 14 38 a.m.1)	The sound area included parts of Echigo, Shinano, Kotsuke, Musashi, and Hitachi.
100	Nov. 3, ,,	2 25 38 p.m.1)	Detonation heard at Naganohara and Iwamrata. There was some ash-precipitation at Yokohama and the vicinity in the morning and between 4 and 5 p.m.
101	,, ,, ,,	5 15 — p.m.	Detonation heard at Naganohara and Iwamrata.
102	,, 4, ,,	8 35 — a.m.	Detonation heard at Iwamrata, Naganohara, and Kusatsu.
103	,, 5, ,,	10 57 — a.m.	Detonation heard at Iwamrata.
104	,, ,, ,,	4 20 — p.m.	*Do.*
105	,, 6, ,,	6 04 49 a.m.1)	Detonation heard at Naganohara and Maebashi.
106	,, ,, ,,	1 22 16 p.m.1)	Detonation heard at Naganohara and Maebashi. Some ash-precipitation at Shiobara.
107	,, ,, ,,	7 36 16 p.m.1)	Detonation of long duration, heard at Naganobara, Sannokra, and Takasaki, with ash-precipitation in Tone-county, prov. of Kotsuke.
108	,, 14, ,,	11 11 55 a.m.	Eruption witnessed from Asama Pasture Ground.
109*	,, 20, ,,	3 40 35 p.m.	Sounds like distant thunders heard at Maebashi. There was some precipitation of ashes (sands) at Naganohara.

1) Time of earthquake occurrence in Tokyo.

Among the outbursts tabulated above, Nos. 76, 77, 78, 80, 82, 84, 85, 90, 91, 92, 93, 94, 96, 97, 98, and 99 were strong detonative explosions, while Nos. 86, 95, 95′, 95″, and 109, were powerful non-detonative eruptions. The greatest monthly frequencies of 7, 8, and 10, occurred respectively in June, July, and November of 1913.

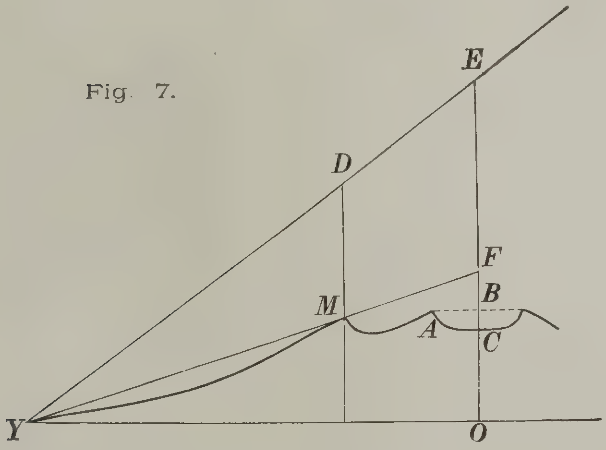
3. *Detonative and non-detonative eruptions of Asama-yama.* The eruptions of the Asama-yama may be divided into the two classes of *explosive* and *non-explosive* outbursts, these being respectively *detonative* and *non-detonative.* A strong explosion is accompanied by a loud detonation or sound shock, like heavy thunder or artillery peals, shaking houses violently and not rarely breaking window panes even at Karuizawa, Komoro, Iwamrata, etc., places situated at the radial distances of 11 to 16 km from the crater. A non-explosive eruption is, even when very strong, not accompanied by any detonation, save feeble sounds like that of a running train or rushing winds. The present author has several times witnessed moderate eruptions of this category from the crater wall itself, no explosive sound being even there perceived at all.

The detonation of an explosion, which is always short in duration, is probably caused by a sudden formation or breaking open of a new vent at the crater bottom, where the lava surface was hardened into a solid layer. On the other hand, the non-explosive eruption, whose duration is generally more or less long, consists of an abundant ejection of smokes, ashes, and rock fragments, in consequence of a powerful outburst along a pre-existing crevice or channel. According to these points of view, the detonative explosions of the. Asama-yama may be regarded more as of the nature of a surface disturbance which creates a great deal of air waves, and the non-detonative eruptions that of a deep-seated action involving a considerable amount of energy to be converted in a large measure to earthquake vibrations. From the tromometer diagrams obtained in Tokyo, it is clear that the Asama-yama eruptions of the latter sort cause generally much greater shakings of the ground than those of the former.

4. ***Height of smoke ascent.*** In the case of a strong eruption, whether detonative or non-detonative, the smokes ascend sometimes to a considerable height. Thus, on the occasion of the non-detonative eruption of Nov. 20th, 1913, which the author witnessed from Kutsukake, the eddying smoke column ascended with a small deviation from the vertical, to a height of about 7,500 m above the mountain top, or 10,000 m above sea-level, breaking through a layer of strato-cirrus, so that the round top was covered with white cloud envelope. As the ascent took about 5 minutes time, the approximate velocity of the vertical progress was on the average some 25 m per sec. Subsequently the smokes were thrown gradually eastwards to an inclination angle of about 45°. The eruption was accompanied for about 10 sec. by dull sounds, like those of distant gun reverberations, causing at the above named village slight shakings of the shojis. The ash-streamers were observed to fall down first 1 minute or so after the commencement. When first looked at, a few seconds after the perception of the feeble eruption sounds, namely, about 30 sec. after the actual occurrence of the outburst, white smokes were already issuing from a great number of points at the Tengu-no-roji on the SE base of the Maikake-yama, and at the Jigoku-zawa on the S. flank of the Asama-yama; these being no other than the small conflagrations of grass and trees caused by the precipitation of hot lava fragments.

As an instance of small non-explosive eruption, may be mentioned that of July 2nd, 1912, at $5^{h} \cdot 29^{m}\ 21^{s}$ a.m., which the author witnessed from the Yuno-taira observatory. This consisted in the emission of a large amount of black smokes, which ascended vertically to the height equivalent to the elevation of the Maikake-yama, or the space of about 1680 m (EF in the accompanying figure) in the time interval of $2^{m}\ 30^{s}$, the mountain having previously been perfectly calm. The smokes were then thrown toward the SSE. This outburst, which was accompanied by a rushing sound like that of wind blowing, gave on the tromometer record at Yuno-taira a diagram consisting of regular minute serrations. (See Fig. 60.) The approximate time interval between the 1st appearance of the smokes over the Maikake-yama and the actual commencement of the eruption was some 30 sec., the mean rate of the vertical ascension being thus some 1970 m/180 sec. = 11 m/sec. This velocity is probably little different from that of the upward current, which must always exist to a greater or smaller extent over the Asama-yama crater, a sort of huge natural furnace.

Fig. 7.



A....WSW crater edge.

C....Crater bottom.

M....Maikake-yama.

Y....Yuno-taira observatory.

$\angle MYO = \angle EYM$.

Height of M above Y = 570 m.

" B " = 580 m.

" C " = 460 m.

YO = 2300 m. CF = 290 m.

EF = 1680 m.

YO = Level of Yuno-taira.

5. *Precipitation of lava fragments and ashes.* It is doubtless due to the great violence of the upward rush of the steam and gases suddenly liberated by a strong eruption that, not only the ashes and sands, but lava fragments of no insignificant dimensions are often carried along with the ascending smoke column to be dropped down after a considerable time interval at places several kilometers distant from the crater. Thus on the occasion of the eruption of Nov. 20th, 1913, which was not explosive, (§ 4), my assistant, Mr. T. Yoshida, observed at the Asama Pasture Ground the time of arrival of the sound of the eruption to be $3^h\ 41^m\ 08^s$ p.m., while it was first $7^m\ 28^s$ later, or at $3^h\ 48^m\ 36^s$ p.m., that the smoke column, gradually wafted from over the crater, reached the sky above the station in question and began to drop down lava pieces, some of which were about 2½ cm in length and 1 cm in thickness, and weighed 5.0 to 6.6 grams; the precipitation having continued for $2^m\ 20^s$. Again, on the occasion of the smaller non-explosive eruption of Nov. 14th, 1913, (Fig. 49), the smoke column reached the zenith of the Wakasare Cottage first about 5 min. after the volcanic sound had been heard, and then there dropped down lava fragments several of which were 5 to 6½ cm in length and 1½ cm in thickness, and weighed 50 to 75 grams; being too hot at the moment of their fall than to be safely touched with hand. As the distances of the Asama Pasture Ground and the Wakasare Cottage from the crater are about 6350 and 5200 m, the velocities of the horizontal progress of the smoke column on the two above-mentioned cases were respectively about 13½ and 16 m/sec. It may be remarked that the lava fragments, which are suspended in the ascending smoke column, are always more or less platy in shape. In the case of the eruption on Dec. 14th, 1912, the time of commencement and the duration of the ash-precipitation at the different places were as follows :—

Place.	Distance from Asama-yama.	Time of commencement of ash-precipitation.	Duration of the ash-precipitation.
Maebashi.	50 km	$10^h\ 13^m$ a.m.	$1^h\ 40^m$
Utsunomiya.	121	11 27 ,,	50
Otsu (province of Iwaki).	204	0 50 p.m.	2 40

The average transit velocity of the ashes between the three stations of Maebashi, Utsunomiya, and Otsu, of the radial distances of 50 to 204 km, was 16.4 m/s or about 60 km per hour.

6. *Projection of lava fragments.* Several of the explosions in 1913 were quite strong, throwing out lava fragments to distances greater than in the preceding years. This implies partly an augmentation in the initial velocity, with which the lava fragments were projected out from the crater (§ 1). Let us now find out the relations existing between the projection velocity (v) ; the projection, or elevation, angle (α) ; the inclination angle (θ) of the mountain slope ; the horizontal projection distance (x_0) ; and the angle of fall (φ), at which the projectile strikes the slope ground. Taking the coordinate origin at the source of projection, or the centre of the crater bottom, and the y-axis vertically downwards, we have, for the time t, counted from the moment of the explosion, the following equations :—

$$x = v\,t\cos\alpha\,;$$

$$y = -v\,t\sin\alpha + \frac{1}{2}g\,t^2\,;$$

in which g is the acceleration due to the gravity. For the point S, or the intersection of the path of the projection and the mountain slope OS, whose equation is $y = x\tan\theta$, we have

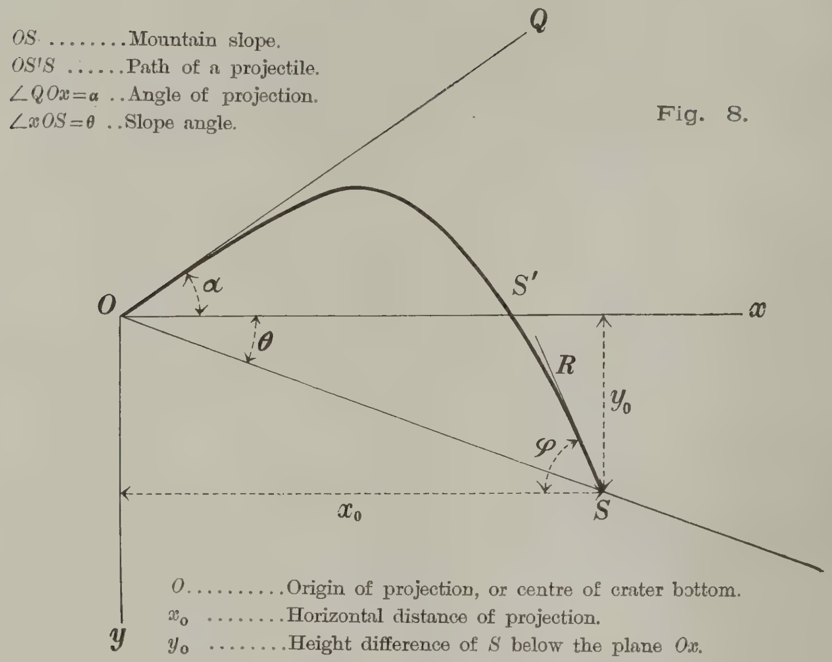


Fig. 8.

OS ....Mountain slope.
$OS'S$ ......Path of a projectile.
$\angle QOx = \alpha$ ..Angle of projection.
$\angle xOS = \theta$ ..Slope angle.

O..........Origin of projection, or centre of crater bottom.
x_0 ....Horizontal distance of projection.
y_0 ....Height difference of S below the plane Ox.
φ ....Angle at which the projectile strikes the ground.

$$x_0 = \frac{v^2}{g}\left(\sin 2\alpha + \cos 2\alpha \tan\theta + \tan\theta\right) \qquad \ldots\ldots\ldots\ldots (1)$$

$$\tan\alpha = \tan\varphi - 2\tan\theta \qquad \ldots\ldots\ldots\ldots (2)$$

$$v^2 = \frac{g x_0}{\tan\varphi \cos^2\alpha + \sin\alpha\cos\alpha} \qquad \ldots\ldots\ldots\ldots (3)$$

These equations enable us to calculate, from the knowledge of the horizontal distance (x_0) of projection and the angle (φ) of fall, the value of the initial velocity (v) of projection, and the angle (α) of elevation. Should the lava fragments be assumed to be projected with one and the same initial speed in the different directions and elevations, the angle α_0 corresponding to the maximum horizontal distance of projection is given, in virtue of (1), by the equation

$$\alpha_0 = 45^\circ - \theta^\circ/2 \qquad \ldots\ldots\ldots\ldots (4)$$

Pl. V.

(Size is indicated in each figure by the annexed cm. scale.)

Fig. 9.

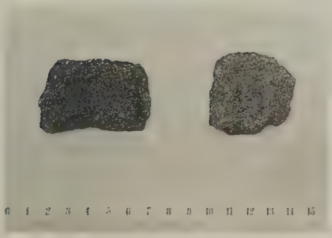


Fig. 10.

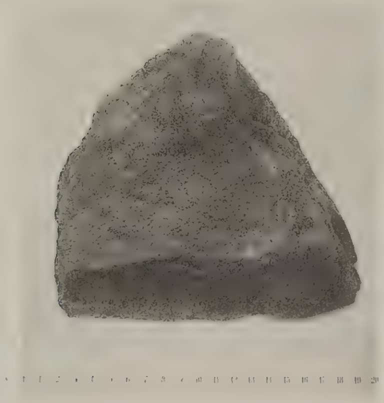


Fig. 11.

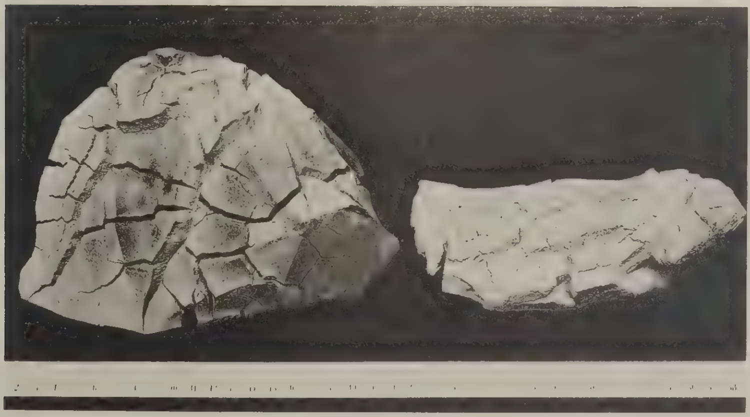


Fig. 9. **Lava fragments suspended in the ascending air current** and dropped down at the Wakasare Cottage. (Eruption of Nov. 14th, 1913.)

Fig. 10. A lava block projected to the Yuno-taira Observatory Ground, burying itself into the soil with the **arrow-head point** downwards. (Explosion of July 19th, 1913.)

Fig. 11. Light bluish-white **bread-crust bombs,** found at the summit of the Asama-yama, after the explosion of Dec. 13th–14th, 1912. (The right-hand side one contains small pieces of **cordierite.**)

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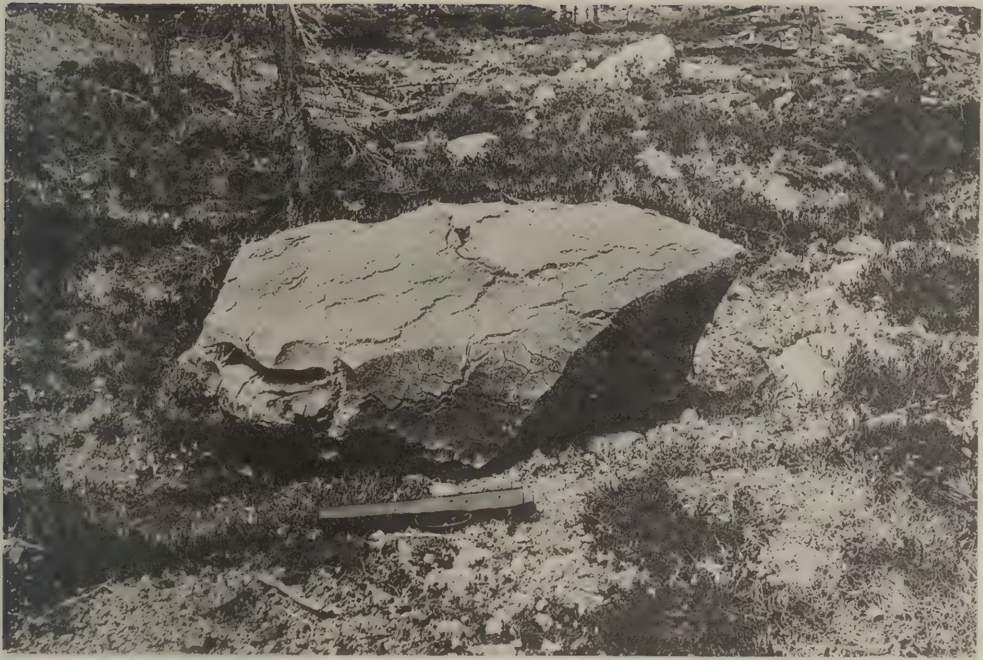

Fig. 12. A large bomb, about 3ft. in length, projected to Tengu-no-roji by the strong explosion of June 17th, 1913. (F. Omori, phot.)

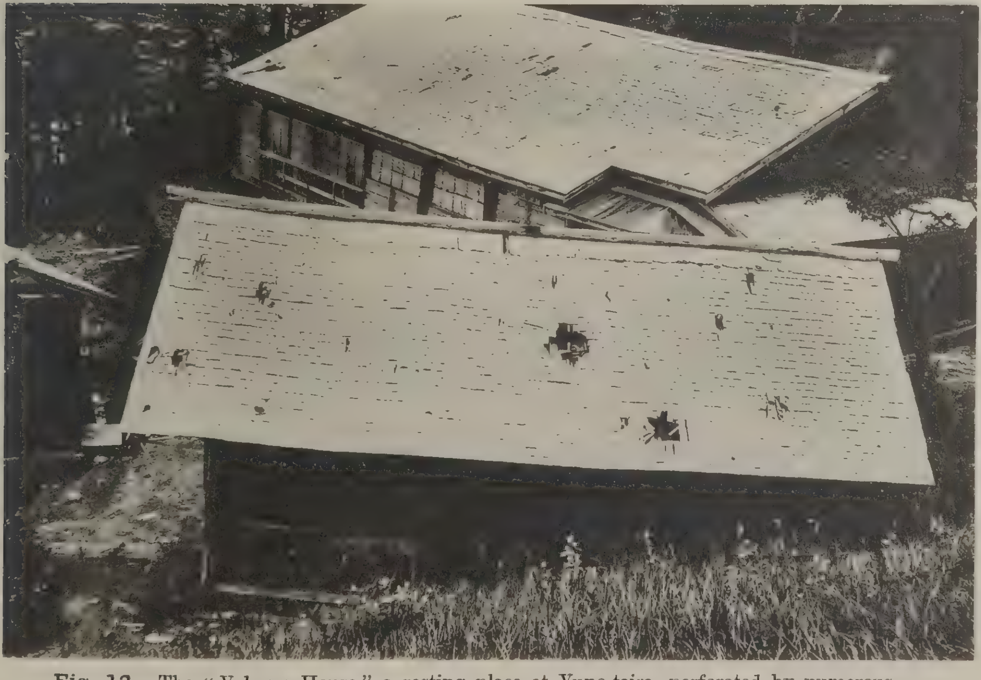

Fig 13. The "Volcano House," a resting place at Yuno-taira, perforated by numerous lava fragments projected out by the strong explosion of Aug. 12th, 1913. (F. Omori, phot.)

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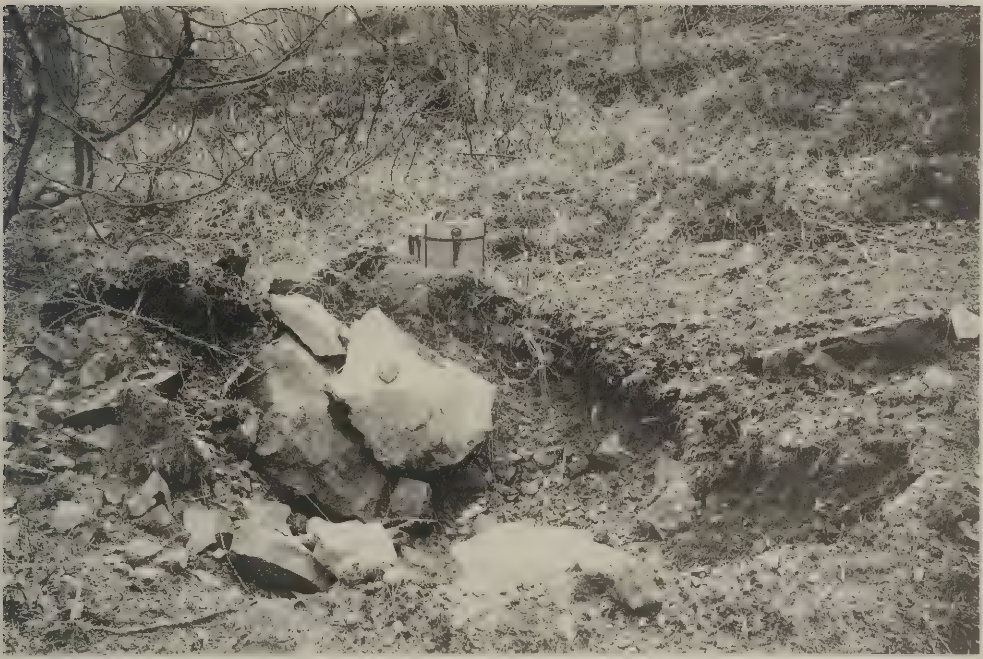

Fig. 14. A hole caused at Tengu-no-roji by the fall of a lava block projected by the explosion, probably of Oct. 22nd, 1911. May 20th, 1912. (F. Omori, phot.)

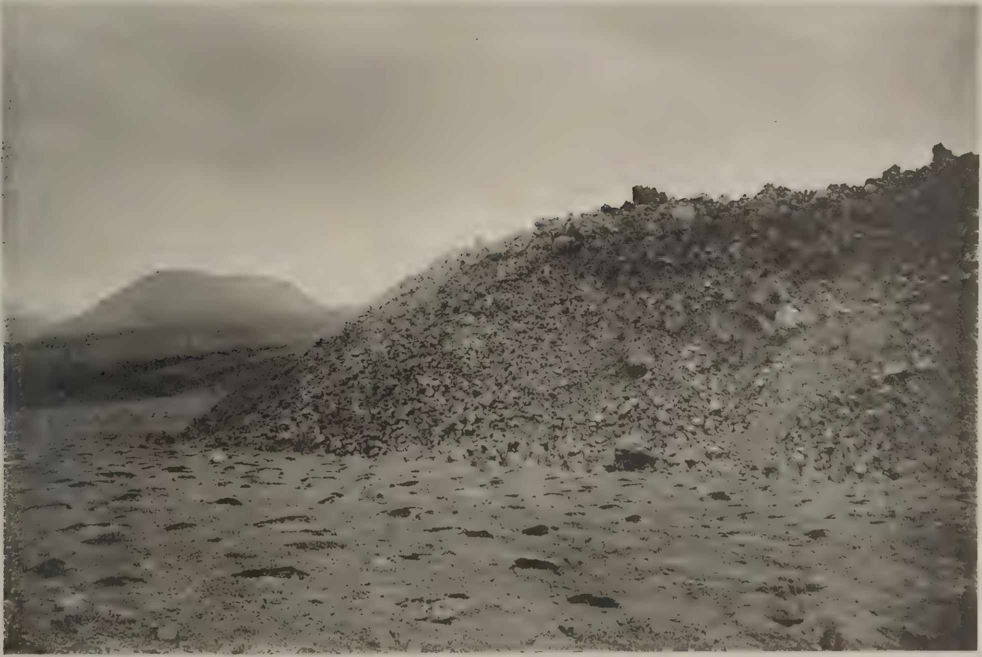

Fig. 15. View of the margin of the Wakasare branch of the lava stream of Temmei (1783), with Ko-Asama on the left-hand side back ground. May 20th, 1912. (F. Omori, phot.)

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It follows that, if $\theta=0$, then α_0 reduces to 45°; i.e., for the case of an explosion from a centre situated on a horizontal plane, the lava fragments projected at an elevation angle of 45° will reach the furthest radial distance. Again, the time of descent, or more strictly, the time interval (τ) between the moment of the explosion and that of fall of the projectile at S, is given by the equation

$$\tau=\sqrt{\frac{2x_0}{g}\left(\tan\alpha+\tan\theta\right)} \quad\ldots\ldots\ldots\ldots\ldots(5)$$

As illustrative examples, I shall next apply the calculations to the cases of a few of the strong explosions of the Asama-yama.

Explosion of July 19th, 1913. According to the eye observation of Dr. K. Aomi, the angle φ for a lava fragment, which fell in the vicinity of the Yuno-taira observatory, at the foot of the Kiba-yama, was about 70°. As the corresponding horizontal distance from, and the height difference below, the crater bottom, are respectively about $x_0=2300$ and $y_0=580$ metres,* we find:—
Mean slope angle $\theta=14°$ Again, according to Equations (2), (5), and (3), we have:—

Angle of projection .... $\alpha=66°$
Time of descent .... $\tau=34$ sec.
Projection velocity .... $v=165$ m/sec.

According to these calculations, the moment of impact of the lava fragment in question was 34 sec. after the commencement of the explosion, or some 26 sec. after the arrival of the detonation at Yuno-taira. There were, of course, cases of earlier descent of lava fragments. Thus, according to the account of the observatory servant, who was sitting by the fire-side at the time of the explosion, the building was struck, as he got out of doors, by the earth splashes caused by the fragments, which fell a short distance to the east, probably some 10 sec. after the arrival of the detonation.

---

* In 1913, the crater bottom was quite shallow.

Explosion of June 17th, 1913. On this occasion a lava fragment of no insignificant magnitude (probably 1 foot or so in dimension) was hurled to a place 768 metres below the Yuno-taira observatory, or about 2930 metres ($=x_0$) horizontally distant from the origin of the explosion, forming there by the force of impact a conical hole on the ground about 3 m in diameter and $1\frac{1}{2}$ m in depth. We may reasonably assume the lava block in question to have been thrown out from the crater at the elevation angle (α_0), which corresponded to the maximum horizontal projection distance, and we obtain from Equation (4), taking θ to be 14°, the value of about 38° for α_0, as follows :—

$$\alpha_0=45°-\frac{\theta°}{2}=38°$$

we further find :—

Angle of impact	$\varphi=52°$
Time of descent	$\tau=24.8$ sec.
Projection velocity	$v=150$ m/sec.

Explosion of Aug. 12th, 1913. On this occasion, the "Volcano House" at Yuno-taira, a low flat wooden building,

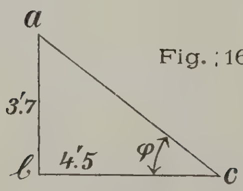


Fig. 16.

($\varphi=40°$)

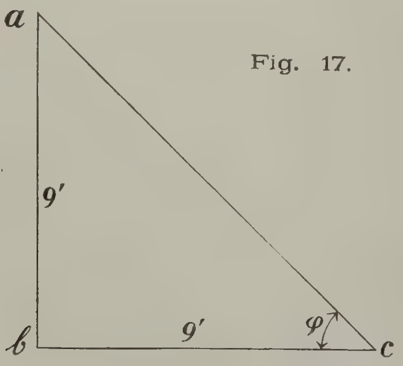
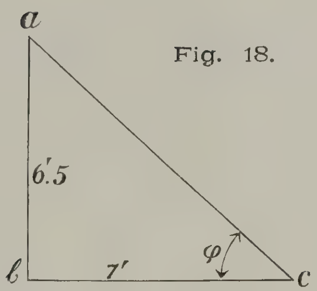


Fig. 17.

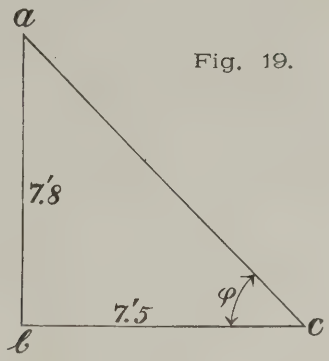
($\varphi=45°$)

Fig. 18.



(φ=43°)

Fig. 19.



(φ=47°)

(a) ....Point where a lava fragment pierced the roof.
(c) ....Point of impact on the floor or ceiling.

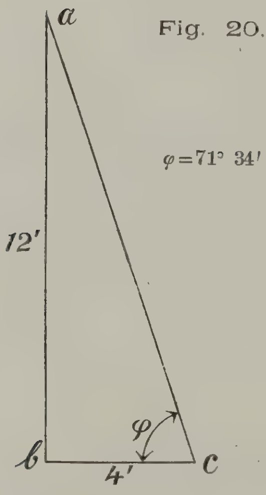
11 m long and 6 m wide, had its thatched roof pierced by no less than 27 small lava fragments. One of these, of about the size of a man's fist, made a hole about 10 inches in diameter on the roof (at *a*, Fig. 16), and scorching the bamboo ceiling (at *c*), finally dropped down to the floor. Another lava block 6″×6″× 3″ in dimensions, made a hole about 10″ in size on the roof of the bath room (Fig. 17) and then strack the ground. A third broke through the roof of a neighbouring room (Fig. 18), and then strack the side wall. A fourth, about 6″ in size, made a hole 12″×6″ in dimensions, on the roof of the stable (Fig. 19), and then strack the ground. The angles of impact in these 4 cases were respectively 40°, 45°, 43°, and 47°, giving the average of 44°. The different buildings were scorched more or less at many points. As the "Volcano House" is about 500 m below, and at 2080 m horizontal distance from, the crater centre, we find :—

$$\text{For } \varphi=44^\circ \ldots\ldots \begin{cases} \alpha=24^\circ \\ v=131 \text{ m/sec.} \\ \tau=17 \text{ sec.} \end{cases}$$

In the case of the eruption under consideration, a curious phenomenon was that there were in the neighbourhood of the observatory several narrow canal-like scratchings of the ground, apparently the effect of the rebounding out of the lava blocks projected at low angles. The largest of these was about 8′ in length, 2′½ in width, and 10″ in depth; the soil and grass being forcibly torn and thrown to distances of 10 m or more. In the case of a small scratching, the length was 1′½ and the width 4″. There were of course numerous instances, in which the lava fragments buried themselves into the soft ground. Thus, a hard angular block about 6″ in length, which fell at a distance of only a few metres from the observatory, was found embedded some 10″ obliquely in the soil. Another, about 5″ in size penetrated to a depth of 6″ at an inclination angle of 30°.

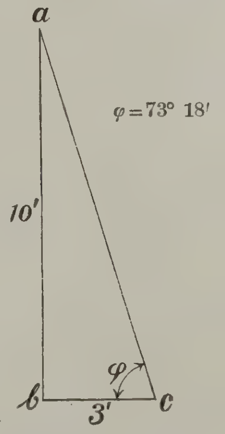
Lava fragments projected to Tengu-no-roji. On occasions of the different strong explosions, lava fragments, of maximum dimension of about 1 m (Fig. 12), were in a great number projected to the Tengu-no-roji (Devils' Throughfare), a picturesque

Fig. 20.



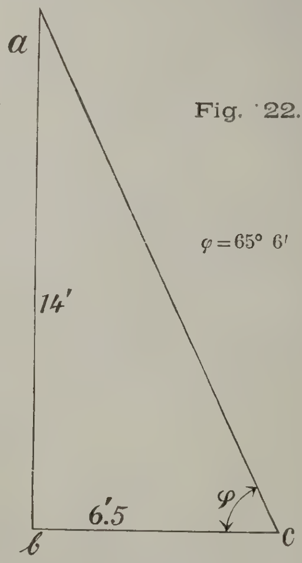
Lava block was an angular piece 1′ in length.

Fig. 21.



Lava block, 1′ cube, made a hole at *c*, 3′ in diam. and 1′ in depth.

Fig. 22.



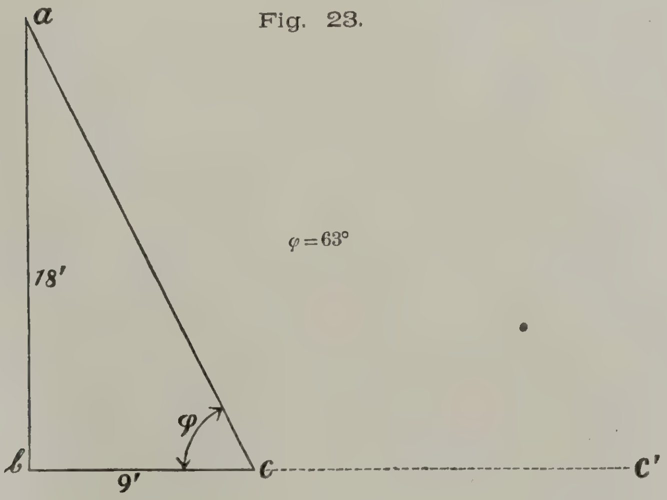
Lava block, embedded at *c*, formed a hole 4′ in diameter and 2′ in depth.

flat enclosure of hard ground at the SW foot of the Maikake-yama. The following determinations of the angle φ were made on July 28th, 1913, from the observations of the height of the point (a), where a falling lava fragment smashed a tree trank (ab), and the horizontal distance between the latter and the place of impact (c) on the ground (bc). The values of the angle of impact (φ) in the three cases figured above (Figs. 20, 21, and 22), which probably relate to the explosion of June 17th, 1913, were respectively 71° 34′; 73° 18′; and 65° 6′, giving the average of 70°. As the place under consideration is at a radial distance of about 1900 m from the crater centre and 470 m below the level of the latter, we find:—

$$\alpha=66^\circ$$
$$v=150 \text{ m/sec.}$$
$$\tau=31 \text{ sec.}$$

Explosion of Oct. 22nd, 1911. At a place called Sai-no-kawara on the plateau (Yuno-taira proper) above the "Volcano House" of Yuno-taira, at a radial distance of about 2000 m to the WSW from the crater centre, and 490 m below the level of the latter, there were found a few large lava blocks, which were projected on the occasion of the explosion in question. One

Fig. 23.



of these smashed a large *Larix leptolepis* tree (*ab*, Fig. 23) at the height of 18 feet (at *a*), and strack the ground with the angle of $\varphi = 63°$ (at *c*), forming a hole 12′ in length, 6′ in breadth, and 4′ in depth. The stone block, which was about 4′ long and 3′ thick, jamped out and rebounded to a further forward distance of 15 feet (to *c*′). The results of the calculations are :—

$$\alpha = 56°$$
$$v = 134 \text{ m/sec.}$$
$$\tau = 26 \text{ sec.}$$

Summary. The estimated values of the initial projection velocity on the occasions of the different explosions are as follows :—

July 19th, 1913	$v = 165$ m/sec.
June 17th, ,, ...	152
,, ,, ,, ...	150
Aug. 12th, ,, ...	131
Oct. 22nd, 1911	134

Thus the projection velocity seems to be *roughly* about 150 m/sec., or, say, from 100 to 200 m per sec., there being no reason to assign any high degree of accuracy to the results of the calculations, in which the air resistance has been entirely neglected. Now, the muzzle velocities of 12 inch and 6 inch naval guns attain respectively the maximum values of about 860 and 900 m per sec., that is to say, some 5 or 6 times greater than the assumed projection velocity of the strong Asama-yama explosions. That the latter can not throw out lava fragments with extremely high velocities is likely enough, as the effect of the outbursts is simply to scatter off the superficial coverings of the molten material filling the crater shaft. Of course, the quantity of the total lava mass thrown out by a strong explosion of the Asama-yama may be some 50 metres cube in volume, and is incomparably larger than that of the projectiles from heavy artillery pieces. The energy of such an explosion will roughly, so far as the projection of lava masses (m) of density ρ $(=2)$ is concerned, be, assuming the initial velocity (v) to be 150 m per sec.,

$$=\frac{1}{2}mv^2=\frac{1}{2}\times 50^3\times 10^3\times 2\times 150^2=10^{13}\times 3 \text{ kilogrammetres,}$$

or about 200 times larger than that of the eruption of the Azuma-san of May 19th, 1893.* In the small explosions, the velocity is smaller, and the courses of the projected lava fragments, which have often tails of steam or gases, can distinctly be followed with the eye from the northern base of the mountain, as was the case, for instance, on Dec. 25th, 1911. Again, it is by no means rare that large lava masses thrown out by the strong explosions were observed even from the towns of Komoro and Kutsukake at the radial distances of 9 to 13 km. (See Fig. 2.)

The lava fragments projected vertically upwards with the initial velocity of, say, 150 metres per sec. will reach to a distance of some 1,100 metres above the crater.

It is to be remarked that the lava masses projected to a more or less considerable radial distance were hard fragments, often with arrow-head like point with which they penetrated into the ground. (See Fig. 10.)

7. *Holes caused by the falling lava fragments.* The hard lava fragments projected out on the occasions of the different strong eruptions of the Asama-yama produced holes as they fell on the ground with considerable force. These were most abundant on the plane grounds of the Yuno-taira and the Tengu-no-roji, and other places within about 2,200 metres horizontal distance from the crater centre. The farthest horizontal distance of projection of about 2,930 metres was reached on the occasion of the explosion of June 17th, 1913, when a hole 3 metres in diameter was formed on the slope of Nagasaka, between Yuno-taira and Ashino-taira. The greatest of the holes, which were circular or elliptical, had the diameter of about 8 m, the depth being, however, comparatively small and less than 1.7 m, as the ground is, at the places under consideration, hard and mixed with rock fragments. In the following table, I give the dimensions of a few holes found at Yuno-taira and Tengu-no roji:—

---

* F. Omori: *The eruption of Azuma-san.* Seismological Journal of Japan, Vol. XIX, 1894.

Place.	No.	Diameters.	Depth.	Remarks.
Tengu-no-roji.	1	ft 15 × 18 ft	ft 4	Relating probably to the explosion of of Oct. 22, 1912.
	2	6 × 6	1½	The stone block was of the size: 2 × 2 × 2′.
	3	6 × 4	1½	
	4	18 × 18	5	Relating probably to explosion of June 17, 1913. The stone block, which jumped out and rebounded several times, was of the size: 2 × 2 × 4′. (See Fig. 12.)
	5	21 × 21	4	
	6	10 × 10	4	The dimension of the stone block was about 2′.
	7	9 × 9	2	(See Fig. 25.)
Yuno-taira.	8	12 × 12	5	(See Fig. 24.)
	9	15 × 12	4	Relating probably to the explosion of Aug. 12, 1913.
	10	12 × 10	4	Relating probably to the explosion of Aug. 12, 1913. The stone block was of the size: 3 × 3 × 1½′.

As will be seen from the above table, the major diameter of the holes was on the average about 4 times larger than the depth, a relation which is contrary to that for holes produced on soft soil. (See below.) Again, the size (length) of the stone block was

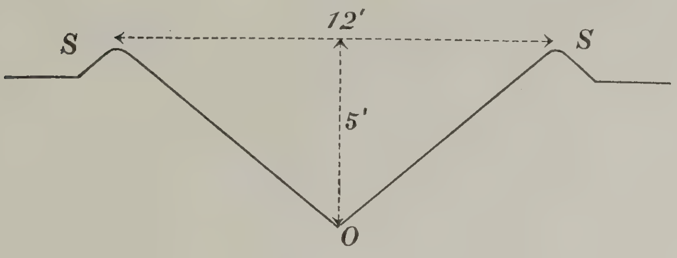


Fig. 24.

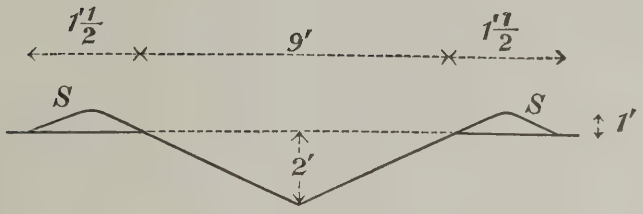


Fig. 25.

only about $\frac{1}{4}$ of the major diameter of the hole it produced. In very many cases, the holes at the Asama-yama were each a perfect inverted cone, as indicated in Figs. 24 and 25, being usually furnished with a ridge along the circumference, or part of it, (S in the figures). If the ground had been covered with grasses, the latter were found at the ridge, whose maximum height was 3 feet, turned upside-down and struck or splashed forcibly outwards, due to the force of the impact of the falling lava mass, often exploding with great violence, such that its fragments and the smashed plants were, in the case of No. 9 found shot off to the distance of about 35 feet from the centre of hole. A lava block, about 1 ft. in size, which fell on soft soil at a distance of 110 feet from the observatory, splashed earth to the doors of the building.

7′. *Digression: holes in the case of Azuma-san eruption.* The formation of the holes, which is a phenomenon almost common to all explosive eruptions, has been brought into notice by the late Professors S. Sekiya and Y. Kikuchi in their reports on the

Bandai-san outburst of 1888. On the occassion of the eruption of the Azuma-san*, in the Fukushima prefecture, on June 4th, 1893, numerous holes were produced by the projected rock fragments, which fell on the marshy plain, called the Numa-no-taira, the site of the old crater. As the soil was soft, the holes remained perfectly clear in outline, and the depth was generally a little larger than the major diameter of the opening, as will be seen from the following list of the measurements :—

No.	Diameters.	Depth.	Remarks.
1	65 cm	90 cm	
2	25	23	
3	7½	15	
4	22	40	
5	20	90	
6	40	40	Stone block, 12 × 12 × 6 cm, buried edgewise. (Fig. 26).
7	24 × 17	> 14	(See Fig. 27.)
8	200	270	Stone block was about 60 cm in size. (Fig. 28.)

Fig. 26.

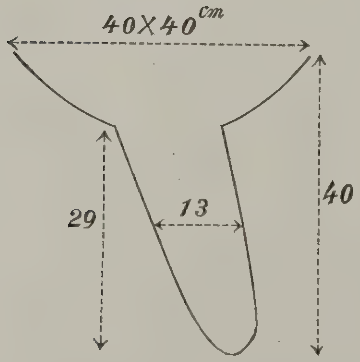
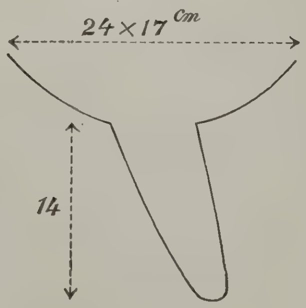


Fig. 27.



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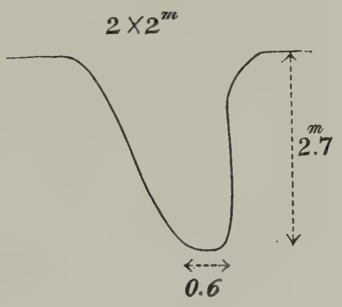
* An account of the eruption is given in the Seismological Journal of Japan, Vol. XX, 1894.

Fig. 28.



As indicated in Figs. 26, 27, and 28, the hole, whose axis was more or less inclined away from the direction of the crater, was generally of a compound form, being made up of the wide and shallow depression and a narrow deepening. The hole No. 8 (Fig. 28) was like a large paraboloid. The size of the stone block was in these cases only about one-third of the diameter of the mouth opening.

8. ***Specific gravity of Asama-yama lava.*** The following table gives the list of values of the specific gravity of a few specimens of the Asama-yama lava, relating mostly to the eruptions in 1913. It will be noted that the specific gravity of the massive lava pieces (i and ii) was about 2.5; while that of the bread-crust bombs and scoriae pieces found near the mountain summit was, on the average, about 1.1, being not much different from that of the ashes. The specific gravity of the pumice was about 1.2.

Specimen.	Specific Gravity.	
(i) Massive lava pieces *projected* to the vicinity of Yuno-taira observatory, or to Tengu-no-roji.	2.42 2.51 2.58 2.29	mean, 2.47
(ii) Lava fragments *dropped down* at Wakasare from among the smoke columns.	2.82 2.36 2.29	
(iii) Bread-crust bombs found at the summit.	0.90 1.04 0.82 1.36	mean, 1.07

Specimen.	Specific Gravity.
(iv) Large scoriae pieces.	0.97 1.31
(v) Pumice which were *dropped* down at Wakasare.	0.86 0.83 0.60
(vi) Ashes, which fell at Wakasare.	1.32
(vi) ” ” ” ” Kumagai.	1.05

9. *Emission of smoke.* In the ordinary, or non-eruptive, times, the large smoke masses of white or gray colour come out from the crater in detatched clusters often at more or less regular intervals. Such can be seen more distinctly when winds are blowing strongly over the mountain, as was the case on July 27th, 1913, when successive pieces of cotton-ball like smokes were swiftly carried eastwards. (See the illustration, Fig. 5.) The following is a part of the list of the times of appearance of the smoke masses over the summit, observed on the above-mentioned day from the Yuno-taira observatory:—

h m s
11 05 24 a.m.
05 50
06 10
06 35*
06 51*
07 35
08 08
08 22
08 54*
09 52
10 15*

h m s
11 10 50 a.m.
11 13
11 34
12 28
12 44
13 21*
13 54
14 14
15 13
15 41
15 57

h m s
11 16 20 a.m.
16 51
17 45
18 00
18 13
18 50*
18 56*
19 31
20 07
20 26*
21 19

h m s
11 22 21 a.m.
23 08
24 15
24 55
25 36
25 54
25 30
27 07*
28 06
28 20
28 36

$11^h\ 29^m\ 24^s$ a.m.
29 52
30 48
31 06
31 36
31 58

$11^h\ 32^m\ 19^s$ a.m.
33 04
33 36
34 14
34 44
35 40*

$11^h\ 36^m\ 28^s$ a.m.
37 04
37 44
38 30
39 11
40 06

$11^h\ 40^m\ 24^s$ a.m.
40 40
41 33

* Comparatively larger ones.

The time interval between the successive emissions of the smoke masses, which varied between 13 and 62 sec., was most frequently included between 16 and 23 sec., and, to a less extent, between 35 and 38 sec., and betweeh 53 and 59 sec., giving the average values respectively of 19, 36, and 56 sec. Of these three values, the 1st may be taken as the fundamental interval, and the two latter as its multiples.

As a case of the occurrences at close intervals of the small non-explosive eruptions, which were strong enough to be registered by the tromometers at the Yuno-taira observatory, we may take the 135 outbursts observed on Oct. 2nd, 1912, between $0^h\ 0^m$ and $1^h\ 04^m\ 39^s$ a.m. According to Table II, the *Bulletin*, Vol. VI, No. 2, the successive time differences, which varied between 10 and 82 sec., were as follows:—

Interval.	Frequency.	Interval.	Frequency.	Interval.	Frequency.	Interval.	Frequency.
10 sec.	1	18 sec.	3	26 sec.	4	34 sec.	0
11	3	19	7	27	8	35	3
12	4	20	5	28	5	36	1
13	1	21	7	29	3	37	1
14	4	22	6	30	4	38	1
15	7	23	3	31	3	39	3
16	4	24	4	32	4	40	1
17	9	25	2	33	1	41	2

Interval.	Frequency.	Interval.	Frequency.	Interval.	Frequency.	Interval.	Frequency.
42 sec.	0	46 sec.	2	58 sec.	1	73 sec.	1
43	2	47	3	61	1	81	2
44	3	53	2	65	1	82	1
45	1	57	2	70	2		

From the above table, it will be noticed that the interval in question was in the 100 out of the total number of the 135 were included between 11 and 32 sec., while it was specially frequent between 15 and 22 sec. This last feature is similar to the preponderance of the value of about 19 sec. in the cases of the smoke emissions in the ordinary times, before considered.

On July 27th, 1913, the smokes were carried by the strong winds along the south-eastern slope to the mountain base, and constituted in the evening hours a light yellowish misty layer extending over the plains below, which caused some ash-precipitation at Miyoda, Komoro, and neighbouring places. It is evident that the strong explosions send the smokes into a considerable height, thence to be generally carried eastwards by the upper air current, differing in this respect from the small eruptions or the ordinary non-explosive smoke emissions, which cause ash-precipitation in the immediate neighbourhood of the mountain in obedience to the surface winds.

CHAPTER II. SOUND AREA AND ASH-PRECIPITATION ZONE.

10. The sound areas and the ash-precipitation zones of the 11 typical explosions in the three years 1909 to 1911 have been described in the preceding volume of the *Bulletin*. I now proceed to consider the cases of the 12 strong outbursts in 1912 and 1913, whose dates and times of occurrence are as follows :—

(1)	Dec.	14th,	1912;	9.	23.	00	a.m.
(2)	May	16th,	1913;	4.	41.	00	p.m.
(3)	,,	29th,	,, ;	10.	44.	12	a.m.
(4)	June	17th,	,, ;	10.	47.	41	p.m.
(5)	,,	20th,	,, ;	4.	06.	47	a.m.
(6)	,,	26th,	,, ;	8.	09.	40	a.m.
(7)	,,	26th,	,, ;	11.	41.	59	p.m.
(8)	July	13th,	,, ;	4.	01.	19	p.m.
(9)	,,	19th,	,, ;	0.	54.	03	p.m.
(10)	Aug.	12th,	,, ;	11.	20.	33	p.m.
(11)	Sept.	21st,	,, ;	1.	50.	59	p.m.
(12)	Oct.	26th,	,, ;	3.	14.	38	a.m.

The sound areas and ash-precipitation zones of these explosions present, as will be seen from the illustrations in Figs. 29 to 44, many interesting characters, which were not fully exhibited in those of the previous outbursts.

11. *Eruption of Dec. 13th—14th*, 1912. According to the report of Mr. Tsuchiya of the Wakasare Cottage, the volcanic sounds were heard from 8.20 a.m. on the 13th, there being eruptions at 11.40 a.m. and 2.05 p.m. in the same day. After the detonation at 7.06 p.m., the eruptions became stronger and continuous during the night, the mountain top being covered by the red hot rock fragments projected out like fire-works. The force of the eruption was augmented from about 9.25 on the next morning, the intensity of the detonations being such that, from 10 a.m., the doors and shojis began to be thrown down. The smokes were carried by winds toward the NE, causing in the neighbourhood of the Ko-Asama the precipitation of sands, small rock fragments, and pices of light white snow-like pumice stones, about

10 cm. in maximum dimension. The outbursts began to decrease in violence from about the noon and ended at about 3.50 p.m.

At Karuizawa, about 11 km to the ESE, the disturbances began at about 1 p.m. on the 13th, the detonations becoming strong enough to shake the houses and break window panes since about 11 p.m. on the same day. On the morning of the 14th, from about 8 o'clock, the lava pieces thrown out from the crater could be distinctly observed with naked eye, resembling groups of flying birds. That some of the projected masses must have been several metres in dimension may be inferred from the photograph of the eruption (Fig. 2), taken at about 10 o'clock on the morning of the 14th from Komoro, a town situated 13 km to the SW of the crater.

At Iwamrata, 16 km to the S 17° W of the mountain, the detonations, which were heard from 7 a.m., became very strong at 11 a.m., when the lava pieces were observed to fall to the NW side of the top, the smokes being thrown eastwards.

On account of the fine quiet weather prevailing at the time of the eruption, the smokes were visible also from Ueda and Nagano, at the radial distances of about 24 and 44 km respectively to the W and the NW of the mountain. Mr. Nishizawa, Director of the Nagano Meteorological Observatory, observed with a hand level the altitude of the smokes at 10 and 10½ a.m., when the eruption was most intense, to be 7°.0 to 7°.1, giving the height of smoke ascent of about 5.4 km above sea-level or about 3 km above the top of the volcano. At Ueda, Professor Y. Tsukiji, of the Sericultural College, estimated the maximum altitude of the smokes to be about 2½ km above the mountain. The ash-precipitation zone and the sound area are shown in Fig. 29.

Ash-precipitation zone. The ash-precipitation zone was a narrow region, which stretched from the Asama-yama, as the apex, in an ENE direction to the coast of the Pacific. Its length was about 115 km and its maximum width about 60 km, including Karuizawa and vicinity, and parts of the provinces of Kotsuke, Shimotsuke, Hitachi, Iwaki, and Iwashiro. The ash-precipitation commenced on the 14th at different moments in the various provinces, according to their radial distances, approximately as follows:—In Kotsuke, from 9.50–11.00 a.m.; in Shimotsuke, from 10.45 a.m.–2.00 p.m.; in Hitachi, from 1 p.m.; and in Iwaki, from 0.50–2.50 p.m. The time of commencement and the duration of the ash-precipitation at the different meteorological stations were as follows:

Meteorological Station.	Radial distance $=x$	Time of commencement of ash-precipitation.	Duration of ash-precipitation.
Maebashi.	50 km.	$10^h\ 13^m$ a.m.	$1^h\ 40^m$
Utsunomiya.	121	11 27 ,,	50
Ōtsu (Hitachi).	204	0 50 p.m.	2 40

Thus the precipitation of ashes at the different stations lasted from about 1 hour to about 2½ hours, the amount being nowhere considerable. The velocity of transportation of the ashes between the above mentioned three places, which are situated on, or approximately on, the axial line of the precipitation zone, is found to be, in the mean, about 16.4 m/s, or 59 km/hour as follows:

Stations.	Utsunomiya-Maebashi.	Ōtsu-Utsunomiya.
Difference of the radial distances.	71 km.	83 km.
Difference of the times of commencement of the preoipitation.	74 min.	83 min.
Transportation velocity.	16.0 m/s.	16.7 m/s.

This transportation velocity of the ashes is somewhat smaller than that in the case of the strong explosion of Dec. 7th, 1909, namely, the value of 22 m/s*, due probably to a comparatively small height of ascent of the smokes on the present occasion. If the rate of transportation of the ashes within the first 50 km of the radial distance had been the same as that for the distances of 50 to 200 km, then the approximate time of commencement of the corresponding ash-ejection at the Asama-yama itself would be about 9.23 a.m.

The sound area extended over the 13 provinces of Shinano, Kotsuke, Shimotsuke, Iwaki, Iwashiro, Hitachi, Musashi, Shimosa, Kazusa, Sagami, Izu, Suruga, and Totomi. Roughly it may be regarded as being made up of the following two parts: (i), A zone of circular arc $S_1 S_1$, with a mean internal radius of about 150 km, subtending an angle of about 156°, and extending from the coast of the province of Totomi on the SSW side to the vicinity of the city of Fukushima on the NE side; (ii), A district of an irregular triangle, $S_2 S_2$, diverging from the Asama-yama and the surrounding tract to the E approximately. Apart from these general ash-precipitation and sound areas, the explosion effects were perceived at the neighbourhood of the lake of Suwa (Shinano). The province of Kai and the surrounding region, lying between the southern branch of the arc $S_1 S_1$, and the neighbourhood of the volcano, where no detonation was perceived, may be regarded as a zone of silence; the radius of the latter being not much different from the values of 120 to 150 km for the strong Asama-yama explosions on Dec. 7th, 1909, and Dec. 2nd, 1910,† and for the violent outburst of the Bandai-san in 1888.

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* See the *Bulletin*, Vol. VI, No. 1. p. 69.

† The same volume, p. 76.

A special feature in the Asama-yama eruption of Dec. 14th, 1912, is that the sound zone was not symmetrical to the ash-precipitation zone, which roughly coincided with the northern half of its $S_2 S_2$ portion. This peculiarity might be due to the long duration of the eruption and the comparatively low height of ascent of the smokes.

The approximate times, at which the detonation began to be heard at the different places, are collected in the following table, where (I) includes the districts belonging to the zone of circular arc, namely, (i) Iwashiro and Iwaki, (ii) Hitachi, (iii) Shimosa, Kazusa, and Awa, (iv) Musashi (Kanagawa prefecture) and Sagami, and (v) Izu, Suruga, and Totomi; while (II) includes the districts in the triangular area, namely, (vi) Kotsuke, (vii) Shimotsuke, and (viii) Musashi (Saitama prefecture). The (ii) and (iii) districts of the I group belong also to the II group.

I				II			
	h m		h m		h m		h m
i Iwashiro and Iwaki	8 00 a.m.	iv Musashi (Kanagawa Pref.) and Sagami	8 00 a.m.	vi Kotsuke	8 30 a.m.	vii Shimotsuke	8 00 a.m.
	8 00		9 40		8 50		9 00
	8 30		10 00		9 00		10 00
	10 00				9 00		10 00
	10 20	v Izu, Suruga, and Totomi	7 00		9 15		10 00
			9 00		9 15		10 30
ii Hitachi	9 00		9 40		9 30		11 00
	9 40		9 50		9 30		11 00
	10 30		9 55		9 30		
			10 00		9 30	viii Musashi (Saitama Pref.)	6 40
iii Shimosa, Kazusa, and Awa	9 00		10 00		9 30		7 00
	9 50		10 20		9 40		9 30
	11 00		11 00		9 45		

The time of commencement of the detonation was, for the places of Group I, mostly from 9.00 to 10.30 a.m. For Group II, it was in (vii) Shimotsuke nearly at 10 a.m., being a little later than in (vi) Kotsuke, where the mean value was about 9.20 a.m., due evidently to the greater radial distance of the former. The time interval, during which the sounds were heard at the different places, varied generally from 1 to 2½ hours. At the Mount Tsukuba Observatory, the principal sounds were heard at 9.09.40; 10.18.30; and 11.16.30 a.m. The times of occurrence of the strongest detonation heard at the different places in the province of Kotsuke, were mostly from 9.15 to 9.30 a.m., giving the mean value of 9.24 a.m.

The weathers on the 13th and 14th were as follows:—
[13th, 6 a.m.] In the central part of the Main Island there was a high pressure area of 772 mm, the rest of the island and Shikoku and Kyushu being enclosed in the isobar of 770 mm. [13th, 2 p.m.] Whole of Japan was under the barometric pressure of 768 to 772 mm, the isobars running parallel to the arc formed by the different islands. [13th, 10 p.m.] The isobars were arranged similarly as before, with the difference that a small high pressure area of 772 mm appeared over the provinces of Shinano and Hida. [14th, 6 a.m.] The greater part of the Main Island and the NE portion of Shikoku were covered by a high pressure centre of 770 mm, generally with clear or fair weather. At most of the stations there prevailed complete calm or high wind. On Mount Tsukuba there was at the time *strong* winds in the WSW'ly direction. [14th, 2 p.m.] The pressure was over Japan 764 to 768 mm, and it became generally cloudy, a low pressure area of 760 mm having made its appearance over Lyukyu.

The wind direction and velocity and the cloud amount observed at the different meteorological observatories at 10 a.m. and 2 p.m. on Dec. 14th are indicated in the following table.

TABLE II. WIND DIRECTION AND VELOCITY, AND CLOUD AMOUNT, AT 10 A.M. AND 2 P.M., ON DEC. 14TH, 1912.

Meteorological Observatory.	Wind Direction.		Wind Velocity.		Cloud Amount.	
	10 a.m.	2 p.m.	10 a.m.	2 p.m.	10 a.m.	2 p.m.
Niigata.	SE	SE	m/s. 4.6	m/s. 3.5	10	9
Fukushima.	W	E	0.5	0.7	2	9
Utsunomiya.	S	S	1.2	1.2	2	10
Maebashi.	NNW	N	5.4	1.6	6	8
Choshi.	NNW	ENE	2.1	4.0	5	10
Kumagai.	—	—	0.2	0.2	0	7
Tokyo.	NW	NNW	4.1	2.0	6	10
Mito.	NNW	N	2.3	2.9	9	10
Yokohama.	N	E	2.8	3.2	0	10
Numazu.	ESE	WNW	1.5	1.8	0	8
Hamamatsu.	NE	SE	1.7	1.2	1	5
Kofu.	SSW	S	0.6	1.6	8	5
Iida.	—	—	0.0	0.4	9	10
Matsumoto.	NW	WNW	1.7	1.2	10	10
Nagano.	N	NW	1.3	0.5	8	10

As will be seen from Table II, at 10 a.m., when the eruption was at its height, the wind velocity was at Niigata, Maebashi and Tokyo from 4.1 to 5.4 m/sec., being much smaller at the other neighbouring stations. The direction of wind was N, NW, or NNW at Nagano, Matsumoto, Maebashi, Tokyo, Yokohama, Mito, and Choshi, namely, within the region extending from the vicinity of the Asama-yama in an ESE direction to the Pacific coast; at other places it was irregular, being S, SSW, SE, ESE, W, or NE. On the whole, at 10 a.m. the wind directions at the different places were, with the exception of Numazu, roughly in the sense of the extension of the sound area. Again, at 10 a.m., it was clear or fair at the different places within the latter, with the exceptions of Tokyo, Maebashi, and Mito, where the cloud amount was from 6 to 9. At 2 p.m. on the 14th, the wind velocity at the different places within the sound area was under 3.2 m/sec., the direction being in several instances not much different from that at 10 a.m.

The direction and speed of the upper and middle height clouds on Dec. 14th, 1912, at 10 a.m., were as follows:—[Tokyo.] Lower clouds: direction W; speed=7. (There were no upper and middle height clouds.) [Nagano.] Upper clouds: direction SW; speed=1. [Mito.] Upper and middle height clouds: direction W; speed=1. [Numazu.] Upper clouds: direction W; speed=2.

12. ***Strong Explosions in*** **1913.** Of the sound areas of the 11 strong explosions in 1913, Nos. 2 to 12 (§ 10), that of (4) was the most remarkable and extensive, and consisted, as in the 6 other cases of (7), (5), (3), (8), (6), and (11), each of two detached portions, namely, (i) the *eastern branch*, which enclosed the Asama-yama, and, (ii), the *western branch* which was arranged along an arcual zone extending from the provinces of Izu, Suruga, Totomi, and Mikawa on the SW, to Kaga and Noto on the NW, at a mean distance of some 160 km from the volcano. With the explosions (10) and (9), the western branch was further separated into the SW. and N. parts. Again, in each of the cases of the 7 explosions, (4), (7), (5), (3), (8), (6), and (10), there was a more or less distinct indication of the ash-precipitation zone, whose direction was toward the E, the NE, or the ESE. It was only in the two cases of (2) and (12) that the sound area consisted merely of the eastern branch. In the following pages, I describe the sound areas for the different cases in the order of Nos. 4, 7, 6, 5, 3, 8, 11, 10, 9, 12, and 2.

13. *Explosion of June 17th, 1913, at 10. 47. 41 p.m.* The eastern branch of the sound area (Fig. 30) was roughly an irregular parallelogram, measuring 215 km in the EW and some 170 km in the NNE-SSW direction, whose major diagonal stretched from the locality between the lake of Suwa and the town of Iida in the province of Shinano to the northern part of Hitachi, and whose minor diagonal from the SE part of Echigo to the head of the Tokyo Bay; the approximate distances of its 4 corners from the Asama-yama being as follows:

SW	from Asama-yama	100 km.
NNE	,,	95
ENE	,,	190
ESE	,,	155

The ash-precipitation zone was a narrow band about 15 km in width and 150 km in length, which came into existence first at 45 km from the origin of disturbance and extended eastwards from the SE part of Kotsuke to the Pacific coast at the vicinity of the city of Mito in the province of Hitachi. At Maebashi, the detonation was heard at 9.50 p.m., while the smoke cloud arrived at the zenith 22 minutes later, or at 10. 12 p.m., unattended by the precipitation of ashes.

The western branch of the sound area, which extended from the Pacific to the Japan sea coast, was of an irregular lunar form stretching from Suruga, Totomi, Mikawa, and Owari, on the south, to Echizen, Kaga, and Noto, on the north-west, and surrounding a small tract composed of parts of Mino, Omi, and Ise, where the detonation was not perceived. Its distances from the Asama-yama are as follows:—

Furthest distance (outerside)	275 km.
Nearest distance (innerside)	135
Northern extremity	165
South-western extremity	190

The areas of the two branches were nearly equal to each other.

Meteorological Condition. At 10 p.m. on the 17th, there existed a high barometric area of 760 mm to the S of the Bonin Islands, at a distance of 1100 km off the coast of Japan; while the central and northern parts of the latter was covered by a pressure ranging from 747 to 750 mm, mostly under northerly or westerly winds, due to the presence of a small centre of low pressure of 746 mm off the SE coast of Hokkaido, and of another also of 746 mm at the SE extremity of the Main Island. In Table III, are given the wind direction and speed, air temperature, and cloud amount, for 10 p.m. on the 17th, at the different meteorological stations, divided into two groups, I and II, or those respectively in or near the eastern and the western branches of the sound area.

TABLE III. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT, AT 10 P.M., ON JUNE 17TH, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).		Air Temperature.	Cloud Amount.
I	Fukushima.	NW	4.8	19.°3 C	10
	Utsunomiya.	ESE	1.3	21.4	10
	Mito.	ENE	2.1	17.7	10
	Niigata.	W	6.5	16.8	10
	Maebashi.	WNW	7.3	20.8	10
	Choshi.	NNE	1.8	19.5	10
	Kumagai.	N	6.1	21.2	10
	Tokyo.	NW	1.8	21.1	10

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).		Air Temperature.	Cloud Amount.
	Yokohama.	N	3.1	22.4	10
	Kofu.	WNW	0.9	23.9	10
	Nagano.	N	1.2	16.6	10
	Matsumoto.	S	0.6	17.3	9
	Iida.	N	2.6	17.5	10
II	Numazu.	SSW	4.7	23.1	10
	Hamamatsu.	W	3.7	20.5	10
	Gifu.	WNW	2.8	19.1	10
	Fushiki.	W	0.8	17.3	10
	Nagoya.	WNW	8.8	19.4	10
	Hikone.	NNW	1.0	18.4	10
	Fukui.	—	0.0	17.7	10
	Kanazawa.	SW	3.3	17.5	10
	Takayama.	—	0.3	16.8	10
	Tsu.	SW	3.1	19.1	10

According to Table III, the sky was at 10 p.m. completely cloudy over Central Japan almost everywhere; the air temperature at the different places varying between 16°.8 and 23°.9 C, with the mean of 19°.3 C. The wind velocity attained the highest values of 8.8 and 7.3 m/s respectively at Nagoya and Maebashi, while it was less than 6.5 m/s at all the remaining places. With regards to the group I stations, the wind directions at Fukushima, Niigata, Maebashi, Kumagai, Yokohama, and Iida, where the velocity had the higher values of 2.6 to 7.3 m/s, were N, W, NW, or WNW; at Mito and Utsunomiya, which were situated on or near the ash-precipitation zone, the winds had the velocity of 2.1 to 1.3 m/s in the contrary or eastern directions, namely, towards ENE and ESE respectively. In the case of the group

II stations the winds were uniformly in westerly directions, namely, W, WNW, NNW, SW, or SSW.

14. *Explosion of June 26th, 1913, at 11. 41. 59 p.m.* The sound area (Fig. 34) in this case was smaller in extension than, but similar to, that in the preceding one. The eastern branch was of an elliptic form, with the major and minor diameters respectively of 126 and 82 km, and included nearly the whole of Kotsuke, a small portion of Shinano at its NE boundary, and the SE corner of Echigo. The greatest radial distance of the direct sound propagation was only 96 km, toward the NE from the Asama-yama. There was a very slight precipitation of ashes in Maebashi, at 0^h 56^m a.m. on the 27th, the detonation having been perceived there 1^h 12^m before or at 11^h 44^m p.m. on the 26th. The western branch was approximately a flat triangle in form, with the apex at Hikone on the eastern shore of the lake of Biwa, and with the base stretching from the city of Kanazawa on the Japan sea coast to the neighbourhood of the town of Hamamatsu on the Pacific; the distances of the three corners of the area from the volcano being as follows:—

Furthest distance (W. corner)	245 km.
Nearest ,, (E. side)	433
NNW extremity	174
SE ,,	200

Meteorological Condition. The approximate meteorological conditions at the time of the explosion may be learned from the 10 p.m. values of the wind direction and velocity, air temperature and cloud amount given in Table IV. The air temperature at the different places varied from 15°.0 to 22°.2 C, with the mean of 19° C. Unlike the preceding case, the sky was clear at several of the stations within the western branch of the sound area. The wind velocity was everywhere low, the highest values of 4.0 to 5.6 m/s having been observed at Maebashi, Tokyo, Nagoya, and Choshi. The winds at Maebashi, as well as at the majority of the places in or near the western branch were westerly, i.e. of W, WNW, or NW direction; while in all the space lying to its east and around the eastern elliptical area, the winds were easterly, i.e. of NE, NNE, N, ENE, or ESE direction.

TABLE IV. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT AT 6 A.M., 10 A.M., AND 10 P.M. ON JUNE 26TH, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).			Air Temperature, C°.			Cloud Amount.		
		6 a.m.	10 a.m.	10 p.m.	6 a.m.	10 a.m.	10 p.m.	6 a.m.	10 a.m.	10 p.m.
I	Fukushima.	SSE 1.1	NW 4.7	SE 1.0	16°.8	23°.2	16°.2	7	8	0
	Utsunomiya.	— 0.2	S 5.9	NNE 1.2	19.9	25.5	18.9	4	6	10
	Mito.	NW 1.3	ENE 3.7	NNE 3.3	18.6	24.8	18.4	10	4	10
	Niigata.	NW 2.5	NNE 6.1	NE 1.4	16.2	18.2	15.0	10	10	0
	Maebashi.	NW 5.4	WNW 1.7	SW 4.0	19.1	27.2	19.6	1	2	10
	Choshi.	ENE 2.9	NNE 5.8	ESE 5.6	21.3	23.2	21.3	3	3	8
	Kumagai.	WNW 1.9	SSE 1.7	NE 0.5	19.0	26.7	19.6	2	4	10
	Tokyo.	SSE 1.6	SE 3.0	ENE 4.1	20.2	26.3	22.2	1	6	10
	Yokohama.	N 3.0	NE 2.9	NE 3.3	21.6	24.6	22.0	10	0	0
	Kofu.	— 0.1	W 1.2	W 0.7	18.2	26.2	20.6	10	2	2
	Nagano.	SE 0.5	ENE 4.3	— 0.2	17.1	23.0	16.7	1	1	10
	Matsumoto.	SW 0.5	— 0.3	N 2.2	15.0	21.0	16.8	3	4	8
	Iida.	E 1.7	SW 6.2	NE 1.8	16.2	24.7	18.3	1	1	0
II	Numazu.	ENE 2.9	W 5.2	ENE 0.7	18.4	24.6	20.8	3	1	3
	Hamamatsu.	WNW 3.4	W 6.2	W 2.8	21.0	25.8	22.1	0	0	0
	Gifu.	— 0.3	WNW 5.3	WNW 1.4	18.8	23.3	19.8	7	7	0
	Fushiki.	W 1.2	E 3.3	NNE 2.9	17.8	19.2	17.3	10	10	10
	Nagoya.	NNW 0.6	WNW 4.9	NW 4.1	19.2	26.0	21.2	10	6	4
	Hikone.	— 0.3	W 2.5	NNE 1.7	18.4	22.0	19.2	3	10	0
	Fukui.	S 0.9	NE 1.2	W 1.1	18.6	20.6	17.6	9	10	0
	Kanazawa.	NNW 2.4	WNW 2.6	ENE 2.5	17.6	20.8	17.4	10	6	5
	Takayama.	SE 1.2	NW 3.2	E 1.4	14.7	22.2	15.4	10	9	10
	Tsu.	WSW 4.7	W 4.9	WNW 3.9	19.1	25.7	21.1	9	6	0

15. ***Explosion of June 26th, 1913, at 8. 09. 40 a.m.*** The eastern branch of the sound area (Fig. 32) was small, and included the province of Kotsuke, and small portions of Shinano and Echigo, the greatest distance of the direct propagation being about 75 km toward the E and NNE. The ash-precipitation zone extended eastwards for a distance of about 75 km. The western branch was a narrow arc zone, about 173 km in length, extending from the northern part of Mikawa to the northern part of Owari and the western half of Mino, its distances from the Asama-yama being as follows:—

N end	155 km.	W, or convex, side,	212 km.
SE end	165	E, or concave, „	170

Meteorological Condition. Assuming the meteorological states at the time of the explosion to be represented by the means of those at 6 and 10 a.m. on the 26th, we see that the sky was more cloudy on the Japan sea coast than on the Pacific; the air temperature varying from 17°.2 to 23°.4 C, with the mean of 21°.0 C. The winds, whose mean velocity was everywhere less than 4.8 m/s, were of westerly directions in the region to the west of the line joining the two peninsulas of Izu and Noto, and including the western branch of the sound area. In the provinces to the east of the above-mentioned line, the wind direction was more or less easterly, with the exception of that at Maebashi, which was westerly and identical with the extension of the ash-precipitation zone.

16. ***Explosion of June 20th, 1913, at 4. 06. 47 a.m.*** The eastern branch of the sound area (Fig. 31) included the greater portion of Kotsuke and small boundary tracts of the adjacent provinces of Shinano, Musashi, Shimosa, and Echigo; the greatest distance of the radial propagation being 130 km toward ESE.

The ash-precipitation zone, about 92 km in length and 15 km in maximum width, extended also in the same direction. At Maebashi the detonation was heard at 4.08 a.m., while the smoke cloud reached the zenith at 4.26 a.m.; there being, however, no precipitation of ashes. At Kumagai, the detonation was heard at about 4.30 a.m., the ashes beginning to fall already before 6 a.m. The western branch, which was roughly of a rectangular form, about 230 km in length and 74 km in maximum width, extended from the N part of Owari on the south, in the direction of N slightly W, to Kaga and Noto on the north; the extreme distances from the Asama-yama being as follows:—

W, or outer, side	188 km.	N end	185 km.
E, or inner side	138	S end	225

Meteorological Condition. Assuming the meteorological states at the time of the explosion, namely, at 4.06 a.m., to be represented by the averages of those at 2 and 6 a.m. given in Table V, we see that the air temperature varied between 13°.3 and 20°.1 C, with the mean of 18°.1 C; the sky being, with a few exceptions, fair or clear. At Maebashi and Kumagai, the winds which had the velocities of about 6.7 and 4.3 m/s were respectively in the NNW and WNW directions, these latter coinciding approximately with the extensions of the ash-precipitation zone. At all the other stations, with the exceptions of Numazu, Nagano, and Fukui, where the velocity was low, the wind directions were W, WSW, WNW, NNW, SSW, N, or S. Again, taking the cases of Niigata, Maebashi, Kumagai, Matsumoto, Kanazawa, Hamamatsu, and Tsu, in which the velocity were comparatively high, namely, from 3.6 to 10.5 m/s, the wind directions were W, WSW, SW, WNW, or NW, giving W for the average.

TABLE V. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT AT 2 AND 6 A.M. ON JUNE 20TH, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).				Air Temperature.		Cloud Amount.	
		2 a.m.		6 a.m.		2 a.m.	6 a.m.	2 a.m.	6 a.m.
I	Utsunomiya.	—	0.2	SSW	3.1	17.4°C	19.7°C	10	0
	Mito.	W	1.6	W	2.0	18.7	18.9	5	0
	Niigata.	WSW	10.8	W	10.1	17.0	17.2	9	2
	Maebashi.	N	6.1	NW	7.3	17.8	18.7	1	0
	Choshi.	SW	5.0	N	3.4	19.2	18.7	0	10
	Kumagai.	NW	2.6	W	6.0	19.2	19.6	4	0
	Tokyo.	SW	1.6	NW	1.6	17.6	18.8	0	0
	Yokohama.	SW	2.3	NW	1.2	18.6	19.4	0	0
	Kofu.	S	0.7	S	0.5	16.2	16.8	1	1
	Nagano.	SE	0.9	E	0.9	16.9	16.2	10	0
	Matsumoto.	SW	8.0	SW	1.7	17.9	14.8	10	1
	Iida.	—	0.2	—	0.4	14.5	18.5	0	0
II	Numazu.	E	2.7	ENE	1.9	18.9	19.0	1	0
	Hamamatsu.	W	2.0	W	5.1	19.4	20.7	0	0
	Gifu.	N	0.9	N	1.1	18.0	17.6	1	0
	Fushiki.	SW	4.3	W	1.1	18.5	19.1	9	0
	Nagoya.	N	1.5	NW	1.7	18.5	18.8	10	0
	Hikone.	—	0.4	NNW	1.6	17.0	19.6	2	0
	Fukui.	ENE	1.5	—	0.2	19.4	18.3	10	10
	Kanazawa.	SSW	4.7	WSW	2.4	18.6	18.2	9	7
	Takayama.	W	0.9	—	0.2	13.7	12.9	10	10
	Tsu.	W	1.3	NW	8.2	19.1	20.2	7	0

17. *Explosion of May 29th, 1913, at 10. 44. 12 a.m.* The eastern branch of the sound area (Fig. 33) was an irregular ellipse extending for a distance of 186 km from the NE corner of

Shinano, through Kotsuke, to the NE part of Musashi. The extreme distances of the direct propagation was 138 km to the SSE, and about 50 km to the NNE and NW from the Asama-yama. The ash-precipitation was reported from 3 places as follows :—(1), Naganohara, slight; (2), Jonai-mura and vicinity, near the town of Itsukamachi in M. Uwonuma county (Echigo), from 11 a.m. to the afternoon; (3), Hirose-mura, in K. Uwonuma county (same province), between 3 and 4 p.m. The dotted line in Fig. 33, connecting these 3 places with the volcano, indicates the course of the ash-precipitation zone, which extended about 105 km towards the NNE. The western branch of the sound area stretched from the province of Mino toward the SE over a distance of about 190 km to the Cape Omaezaki (Totomi) and the SW part of the province of Suruga, evidently with some further extension over the Pacific; the extreme distances from the volcano being as follows :—

N corner	160 km.
NW „	230
Cape Omaezaki	202

Meteorological Conditions. At 10 a.m. on the 29th, the air temperature varied from 16.°2 to 22.°9 C, with the mean of 20.°0 C; the sky being entirely overcast almost at all the different places in central Japan. The winds, whose velocity was everywhere very low and less than 4.7 m/s, were various in direction. (See Table VI).

TABLE VI. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT, AT 10 A.M. ON MAY 29th, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).		Air Temperature.	Cloud Amount.
I	Fukushima.	NW	2.2	20.7° C	10
	Utsunomiya.	S	1.7	21.3	9
	Mito.	S	1.1	22.9	10
	Niigata.	NNE	1.8	20.6	10
	Maebashi.	ESE	1.1	21.8	10
	Choshi.	NNE	3.0	20.7	10
	Kumagai.	SSE	0.7	22.0	10
	Tokyo.	NE	2.0	22.3	10
	Yokohama.	E	4.7	20.5	10
	Kofu.	—	0.2	21.2	10
	Nagano.	E	1.2	19.4	10
	Matsumoto.	N	2.2	16.6	10
	Iida.	SW	1.5	16.2	10
II	Numazu.	W	2.8	21.9	10
	Hamamatsu.	E	4.3	20.4	10
	Gifu.	N	0.7	19.6	10
	Fushiki.	NE	1.7	17.0	10
	Nagoya.	S	2.8	21.2	10
	Hikone.	W	0.9	17.2	10
	Fukui.	S	2.1	20.7	9
	Kanazawa.	NW	1.1	19.8	10
	Takayama.	W	2.9	16.5	10
	Tsu.	NE	2.2	20.4	10

18. *Explosion of July 13th, 1913, at 4. 01. 19 p.m.* The eastern branch of the sound area (Fig. 36) was a small ellipse of the major and minor diameters respectively of 53 and 40 km, with the Asama-yama nearly at the centre. The ashes were carried about 20 km to the NE, slight precipitation having taken place at Wakasare Cottage and at the town of Naganohara. The western branch area was in the present case much greater than the above mentioned, and included the three provinces of Totomi, Mikawa, and Owari, and parts of Suruga, Mino, Omi, and Ise, forming an arc extending in the EW direction for the length of about 220 km. The extreme distances of its different points from the volcano are as follows :—

W end	250 km.
E ,,	120
SW ,,	270
S, or convex, side	240
N, or concave, side	165

The detonation was also perceived in the city of Kanazawa at the radial distance of 169 km to the W slightly N.

Meteorological Condition. Assuming the meteorological states at the time of the explosion to be represented by the means of those at 2 and 6 p.m. given in Table VII, we see that the air temperature varied between 21.°3 and 27.°8 C, with the mean value of 26.°9 C ; the sky being generally cloudy at the stations of Group I, but fair at several of Group II. The winds, whose velocity was from 2.2 to 5.6 m/s, were of E, S, or south-easterly directions in the region lying to the E and SE of the Asama-yama, but were mostly of W or north-westerly directions at the places within the western branch area as well as in the provinces situated to its E and N.

TABLE VII. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT, AT 2 AND 6 P.M. ON JULY 13TH, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).				Air Temperature.		Cloud Amount.	
		2 p.m.		6 p.m.		2 p.m.	6 p.m.	2 p.m.	6 p.m.
I	Fukushima.	NE	5.6	ENE	5.3	30°.1 C	24°.4 C	3	10
	Utsunomiya.	S	3.5	S	2.6	27.9	27.1	7	7
	Mito.	E	3.1	ESE	3.5	26.9	23.5	10	10
	Niigata.	N	6.1	N	2.5	22.4	22.6	8	7
	Maebashi.	ESE	6.4	ENE	5.8	28.3	26.5	4	10
	Choshi.	SSE	3.5	SSE	3.6	26.1	23.5	10	10
	Kumagai.	SE	3.2	SE	4.8	29.2	27.3	8	10
	Tokyo.	SE	3.5	S	4.1	28.5	25.4	10	10
	Yokohama.	SSE	3.2	SW	5.4	28.7	25.1	10	10
	Kofu.	SW	2.0	SSW	7.4	32.5	26.6	8	10
	Nagano.	SW	3.2	N	4.3	30.9	24.1	3	10
	Matsumoto.	WNW	2.2	SW	3.4	28.7	27.1	8	9
	Iida.	S	0.9	NE	3.4	30.7	26.1	4	9
II	Numazu.	W	6.0	WNW	5.1	27.5	25.1	9	10
	Hamamatsu.	WSW	4.2	SW	1.7	28.8	27.6	9	10
	Gifu.	W	2.3	S	2.7	31.2	28.3	2	4
	Fushiki.	ENE	3.8	N	2.1	21.2	21.3	8	5
	Nagoya.	SSW	4.2	S	5.4	30.4	28.2	0	9
	Hikone.	NNW	3.4	N	1.9	27.1	26.8	1	4
	Fukui.	N	5.1	NW	4.2	26.7	25.3	4	3
	Kanazawa.	SSW	4.1	NW	4.7	26.3	25.0	7	6
	Takayama.	S	4.9	N	2.9	29.1	25.1	9	10
	Tsu.	ESE	4.2	S	5.9	28.5	27.5	1	7

19. *Explosion of Sept. 21st, 1913, at 1. 50. 59 p.m.* The eastern branch of the sound area (Fig. 35) included Kotsuke and small boundary portions of the two ajacent provinces of Shinano and Musashi; the greatest radial distances being 126 and 90 km respectively to the ESE and ENE. There was no report on the precipitation of ashes. The western branch consisted of the northern and the southern portions; the former being in this case reduced simply to the vicinity of the city of Kanazawa. The southern division was of an elliptic form, extending over a distance of 113 km in the W-E direction from the eastern border of the lake of Biwa to the NW part of Mikawa. The extreme distances of the different points of the western branch area from the Asama-yama are as follows:—

N division (vicinity of Kanazawa)	175 km.
W end (S. division)	250
E end (S. division)	165

Meteorological Condition. At 2 p.m., the barometric pressure was highest (762 mm) over North China, thence decreasing eastwards, to 758–754 mm over the Main Island, at whose SE corner, namely, over the Izu peninsula, there existed a small depression centre of 752 mm. The wind was generally W'ly or NW'ly, except at the vicinity of Choshi, where it was E'ly or NE'ly. The wind velocity was highest at Choshi (NE, 12 m/s), Hamamatsu (W, 7.7 m/s), Niigata (NNW, 7.6 m/s), and Kofu (NW, 7.1 m/s). The air temperature varied from 16°.8 to 28°.8 C, with the average of 21°.1 C. The sky was cloudy or rainy over the greater part of Japan.

TABLE VIII. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT, ON SEPT. 21ST, 1913, AT 2 P.M.

Meteorological Station. (I)	Wind Direction and Velocity (m/s).	Air Temperature. C.	Cloud Amount.	Meteorological Station. (II).	Wind Direction and Velocity (m/s).	Air Temperature. C.	Cloud Amount.
Fukushima.	ESE 1.5	20°.8	10	Numazu.	SSE 3.7	28°.8	1
Utsunomiya.	ESE 1.8	18.1	10	Hamamatsu.	W 7.7	27.1	8
Mito.	ENE 2.9	16.8	10	Gifu.	N 0.7	22.7	10
Niigata.	NNW 7.6	19.0	10	Fushiki.	WNW 2.4	20.7	10
Maebashi.	S 4.2	20.8	10	Nagoya.	WNW 5.6	22.9	10
Choshi.	NE 12.0	18.9	10	Hikone.	NW 3.3	21.0	10
Kumagai.	E 0.7	19.1	10	Fukui.	NNW 3.2	21.8	10
Tokyo.	NNE 4.3	17.7	10	Kanazawa.	NW 2.8	20.7	10
Yokohama.	N 5.7	19.0	10	Takayama.	NNE 1.8	18.1	10
Kofu.	NW 7.1	26.9	10	Tsu.	NNW 6.1	23.4	10
Nagano.	— 0.2	19.5	10				
Matsumoto.	E 1.2	18.5	10				
Iida.	N 2.3	22.0	10				

20. ***Explosion of Aug. 12th, 1913, at 11. 20. 33. p.m.*** The eastern branch of the sound area (Fig. 37) was somewhat rectangular in form, whose two sides were about 150 and 200 km in length, with the mutual distance of 75 km, running in the WNW-ESE direction from the NE part of Shinano, through Kotsuke, to Musashi and the SW corner of Shimotsuke. This explosion was the only instance among the numerous Asama-yama explosions, in which the direct western propagation of the detonation reached to the locality some miles NW of the city of Matsumoto; with the exception of the outburst of May 31st, 1909, in which, however, the sound area was nearly a circle with the volcano for centre. The extreme radial distances were as follows:—

W corner	62 km.	E corner	118 km.
NW „	40	SE „	150

The ash-precipitation zone extended, with the maximum width of 17 km, toward the E slightly S, through a distance of 148 km, to Mount Tsukuba. At Maebashi, the detonation was heard for about 1 min. from $11^h 23^m$ p.m., and the ashes fell there on the next day from $0^h 28^m$ till $1^h 20^m$ a.m., a rain precipitation having thereafter taken place. The amount of the ashes collected on a piece of paper, 80×56 cm in area, was 22 grams. On Mount Tsukuba the ashes continued to fall from 10 (?) p.m. on the 14th till 6 a.m. on the next morning.

The western branch of the sound area was composed of the northern and southern portions, mutually separated at the boundary region of Echizen, Omi, and Mino. The northern division stretched along the Japan sea side, through a distance of about 195 km, including the province of Kaga and parts of Noto and Echizen. The southern division was extensive and stretched in the EW direction for a length of 285 km from the vicinity of Lake Biwa on the W to the Bay of Sagami on the E, including the provinces of Owari and Mikawa, and parts of Omi, Ise, Mino, Totomi, Suruga, and Izu. The distances from the Asama-yama were as follows:—

N end (N division)	187 km.	W end (S division)	270 km.
S „ („)	230	E „ („)	165

Meteorological Condition. According to the weather map for 10 p.m. on the 12th, the atmospheric pressure was high (758 mm) in the vicinity of the Bonin Islands and low (748 mm) in Karafuto. The barometric gradient over Japan was very gentle, the pressure varying only between 750 and 754 mm. The air temperature was, in Central Japan, from 19°.6 to 28°.4 C, with the average of 25°.2 C, while the sky was entirely overcast, with the exception of the cases of Tokyo, Yokohama, and Numazu. (See Table IX.) The wind velocity was greatest, namely, 6.9 to 8.2 m/s, at Numazu, Tsu, and Nagoya. In the eastern and western branches of the sound area, as well as in the space between them, the wind direction was in the main westerly or southerly; while in the region adjacent on the NE side, it was more or less westerly.

TABLE IX. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT, AT 10 P.M. ON AUG. 12TH, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).		Air Temperature.	Cloud Amount.
	Fukushima.	ENE	0.7	23°.7	10
	Utsunomiya.	NNE	3.5	24.1	10
	Mito.	NNE	2.1	27.7	10
	Niigata.	SE	2.2	22.8	10
	Maebashi.	NNW	3.8	25.8	10
	Choshi.	SE	4.3	26.4	9
I	Kumagai.	W	2.5	19.6	10
	Tokyo.	S	3.9	28.4	6
	Yokohama.	SSW	2.2	26.8	2
	Kofu.	SW	1.8	25.9	9
	Nagano.	—	0.0	22.3	10
	Matsumoto.	S	0.7	22.8	10
	Iida.	WNW	2.2	25.4	10
	Numazu.	SW	6.9	27.7	7
	Hamamatsu.	W	1.3	27.6	10
	Gifu.	W	2.7	27.5	10
	Fushiki.	S	4.5	25.6	10

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).		Air Temperature.	Cloud Amount.
II	Nagoya.	W	8.2	25°.3	10
	Hikone.	SE	2.0	24.7	10
	Fukui.	S	0.8	25.8	10
	Kanazawa.	SSW	4.2	24.7	10
	Takayama.	E	1.2	22.5	10
	Tsu.	N	7.6	25.6	10

21. ***Explosion of July 19th, 1913, at 0. 54. 03 p.m.*** The sound area (Fig. 38) was similar to, but a little smaller than, that of the preceding case. The eastern branch was elliptic in form, of the major and minor diameters respectively 110 and 63 km in length; the greatest *radius* being 64 km directed toward the ESE. A slight ash-precipitation was reported from the town of Shimonita at a distance of 31 km to the SE of the volcano. The western branch consisted of the northern and southern portions mutually separated by the boundary districts of Echizen, Omi, and Mino. The northern division included the coast of Kaga and the S. half of Noto, extending for the length of 132 km in the SW-NE direction. The southern division was larger in extension, stretching in the form of a butterfly with wings spread out, through a distance of 210 km and in the WNW-ESE direction from the W. part of Omi to the boundary between the two provinces of Totomi and Suruga; this being, so far, one of the two cases in which the Asama-yama detonation was heard on the W side of the Lake of Biwa. (See also Fig. 30.) The distances of the western branch area from the volcano were as follows:—

N end (N division)	....190 km.	W end (S division)	....267 km.
S „ („)	210	E „ („)	172

Meteorological Condition. According to the weather map for 2 p.m. on the 19th, there existed an atmospheric depression of 740 mm at the N. part of Formosa, while an anticyclone of 762 mm was found to the NE of Hokkaido; the central part of the Main Island being under the pressure of 756 mm. The air temperature varied from 21°.1 to 32°.8 C, with the mean of 27°.9 C, the sky being mostly cloudy. (See Table X.) The wind velocity was over 5 m/s at several of the places, the maximum values being 9.3 and 8.6 m/s respectively at Fukushima and Choshi. The wind direction was more or less easterly in the tract lying to the E and NE of the line connecting the Asama-yama with Nagano and Izu peninsula, while to the W of the latter it was at several places more or less westerly. Again, the wind was northerly along the Japan sea coast, while it was southerly on the Pacific coast.

TABLE X. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT, AT 2 P.M. ON JULY 19TH, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).		Air Temperature.	Cloud Amount.
I	Fukushima.	NE	9.3	26°.6 C	7
	Utsunomiya.	S	3.2	24.9	7
	Mito.	ENE	5.0	23.3	5
	Niigata.	N	5.7	28.6	9
	Maebashi.	ESE	3.5	26.7	10
	Choshi.	SSE	8.6	21.1	10
	Kumagai.	ESE	5.8	27.6	10
	Tokyo.	ENE	4.3	25.8	10
	Yokohama.	NE	3.5	24.6	10
	Kofu.	SW	1.7	32.8	10

Group.	Meteorological Station.	Wind Diretion and Velocity (m/s).		Air Temperature.	Cloud Amount.
II	Nagano.	SE	1.7	30.7 C	3
	Matsumoto.	N	1.2	29.0	2
	Iida.	W	4.1	30.5	7
	Numazu.	S	2.9	28.9	10
	Hamamatsu.	SW	3.4	29.4	7
	Gifu.	SW	0.9	29.0	10
	Fushiki.	N	3.9	26.2	2
	Nagoya.	SSW	5.0	27.9	10
	Hikone.	ENE	2.9	29.0	10
	Fukui.	N	2.8	30.9	9
	Kanazawa.	NW	3.6	30.1	7
	Takayama.	S	1.9	29.5	9
	Tsu.	E	5.7	28.6	6

22. *Explosion of May 16th, 1913, at 4. 41. 00 p.m.* The sound area (Fig. 40) was an oval extending for a length of 140 km in the NW-SE direction, from the boundary tracts of Kotsuke and Shinano to the central part of Musashi; the greatest radial distance of 113 km being directed toward the SE. There was no western branch.

Meteorological Condition. Assuming the state of weather at the time of the explosion to be represented by the means of those at 2 and 6 p.m. given in Table XI, we see that the air temperature varied between 6°.7 and 16°.0 C, with the mean of 11°.8 C; the sky being generally overcast. The wind, whose velocity was generally high and above 10 m/s at a few places, was in the region to the W of the line joining the Asama-yama with the head of the Tokyo Bay, mostly westerly or northerly, such that the average direction may be taken to be NW. On the other hand, at the places lying to the NE of the above-mentioned boundary, the wind direction was northerly or easterly.

TABLE XI. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT AT 2 AND 6 P.M. ON MAY 16TH, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).		Air Temperature.		Cloud Amount.	
		2 p.m.	6 p.m.	2 p.m.	6 p.m.	2 p.m.	6 p.m.
I	Fukushima.	NE 4.9	ENE 3.5	7.0°C	6.4°C	10	10
	Utsunomiya.	NE 4.2	NE 7.1	9.0	7.9	10	10
	Mito.	N 4.5	NNW 8.6	9.2	8.2	10	10
	Niigata.	NE 4.7	NNE 1.5	12.1	11.6	10	10
	Maebashi.	S 1.9	WSW 2.9	12.0	11.1	10	10
	Choshi.	N 14.1	N 15.2	12.8	10.9	10	10
	Kumagai.	WNW 3.4	— 0.2	10.9	11.4	10	10
	Tokyo.	NW 5.2	NNW 7.0	10.0	9.4	10	10
	Yokohama.	NNW 5.3	N 6.5	10.6	11.2	10	10
	Kofu.	SSE 0.7	NW 3.6	13.4	12.8	8	8
	Nagano.	W 7.8	E 2.4	10.5	9.0	10	10
	Matsumoto.	NNE 9.3	N 3.9	12.8	8.8	10	10
	Iida.	SE 1.3	NE 2.5	15.6	12.6	5	6
II	Numazu.	SE 3.2	SSE 2.5	13.9	13.9	10	10
	Hamamatsu.	W 2.3	W 3.8	15.4	16.6	10	10
	Gifu.	W 3.7	NNW 6.9	15.5	14.0	10	3
	Fushiki.	N 5.4	NW 2.6	11.4	10.0	10	10
	Nagoya.	SW 3.1	WNW 10.8	16.6	14.4	10	3
	Hikone.	NNW 5.1	NW 7.9	13.4	12.5	10	10
	Fukui.	NNW 5.0	NNW 4.3	12.9	10.8	10	10
	Kanazawa.	NE 3.9	NNE 4.3	11.5	9.8	10	10
	Takayama.	N 4.2	NW 6.3	11.1	9.2	10	10
	Tsu.	NNW 9.4	NW 11.7	16.6	13.3	10	1

Fig. 29. Sound Area and Ash-Precipitation Zone of the Asama-yama Eruption of Dec. 14th, 1912, at 9.23 a.m.

Sound Area is shaded *red* (thin). Ash-precipitation Zone is shaded *red* (deep).
Places where Detonation was perceived are indicated by *red dots.*

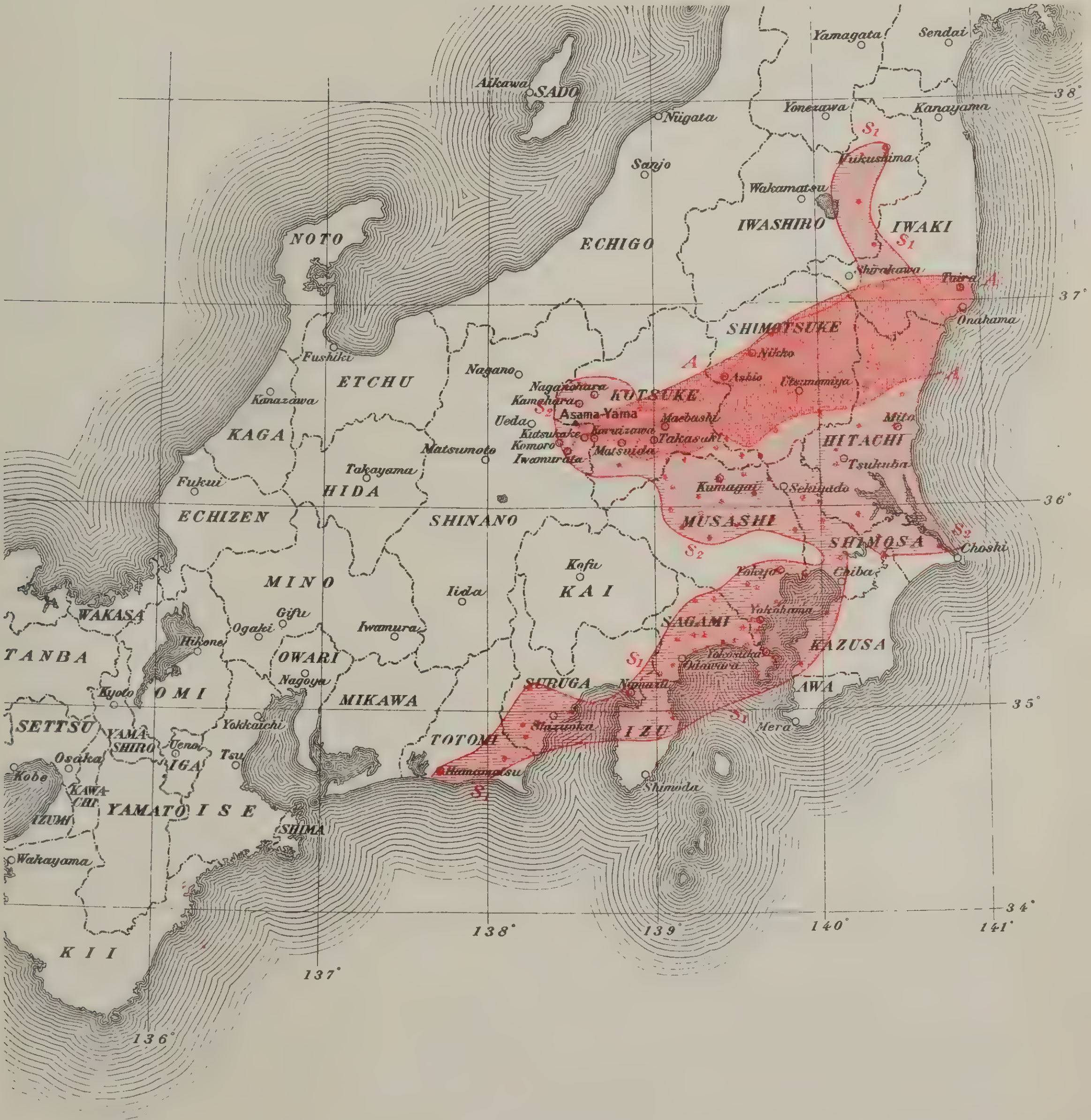

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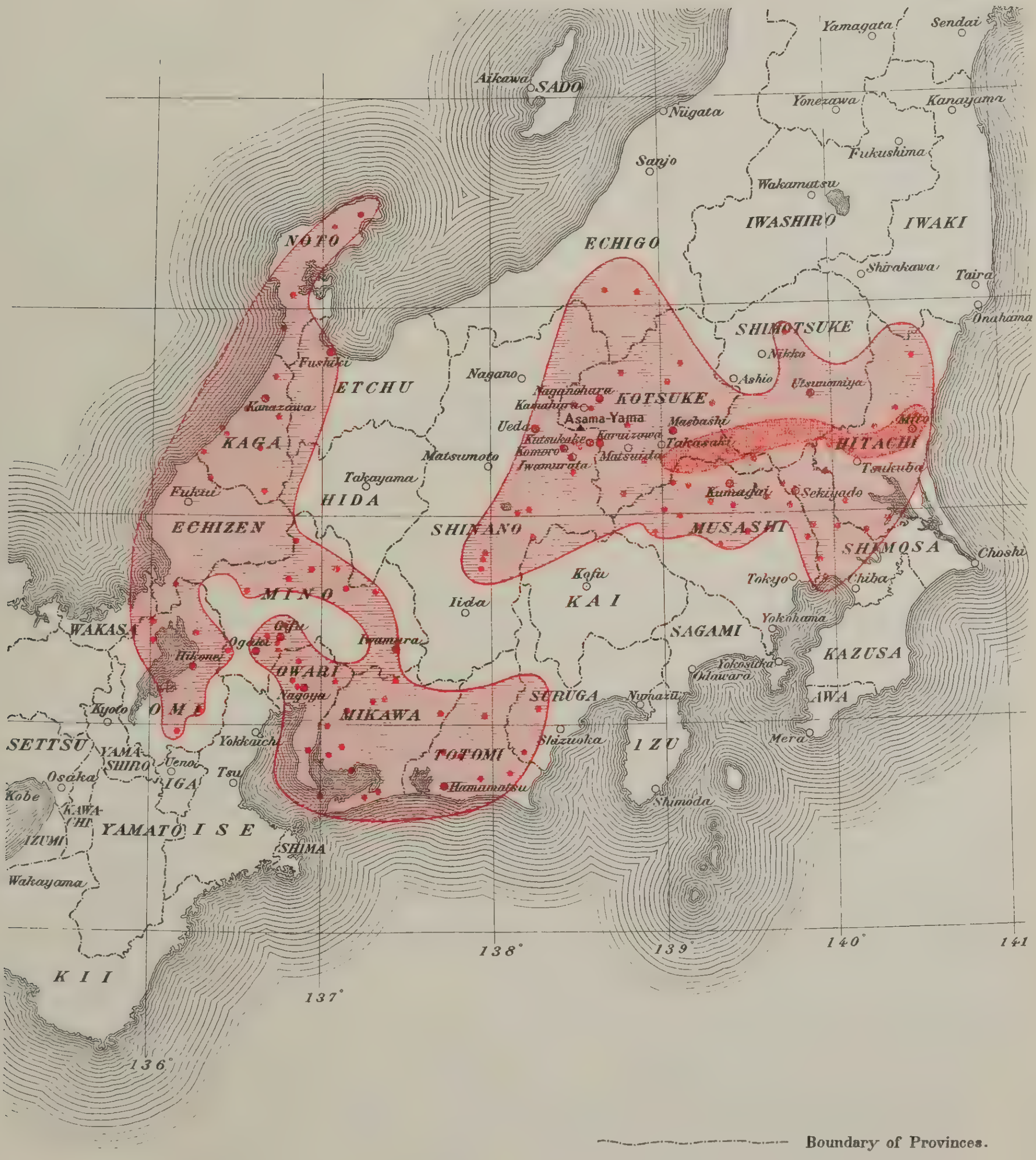
Fig. 30. Sound Area and Ash-Precipitation Zone of the Asama-yama Explosion of June 17th, 1913, at 10. 47. 41 p.m.

Sound Area is shaded *red* (thin). Ash-precipitation Zone is shaded *red* (deep).
Places where Detonation was perceived are indicated by *red dots.*



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Pl. X.

Sound Area and Ash-Precipitation Zone of Asama-yama Explosions.

Sound Area is shaded *red* (thin). Ash-precipitation Zone is shaded *red* (deep).

Places where Detonation was perceived are indicated by *red dots.*

Fig. 31. June 20th, 1913, at 4. 20 a.m.

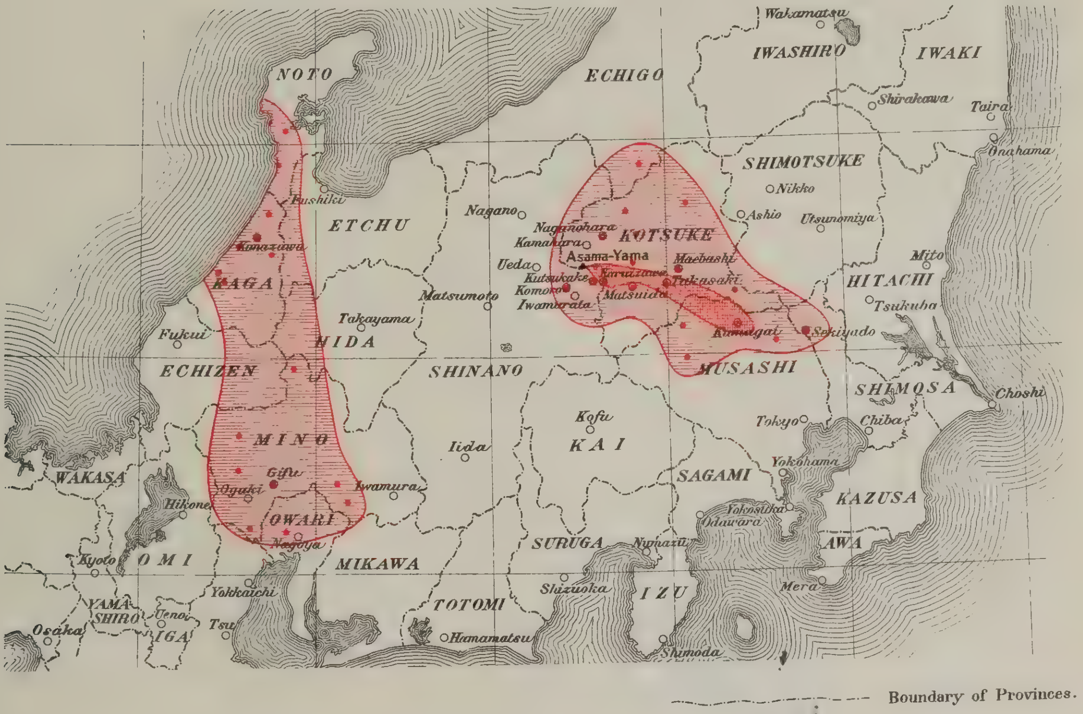
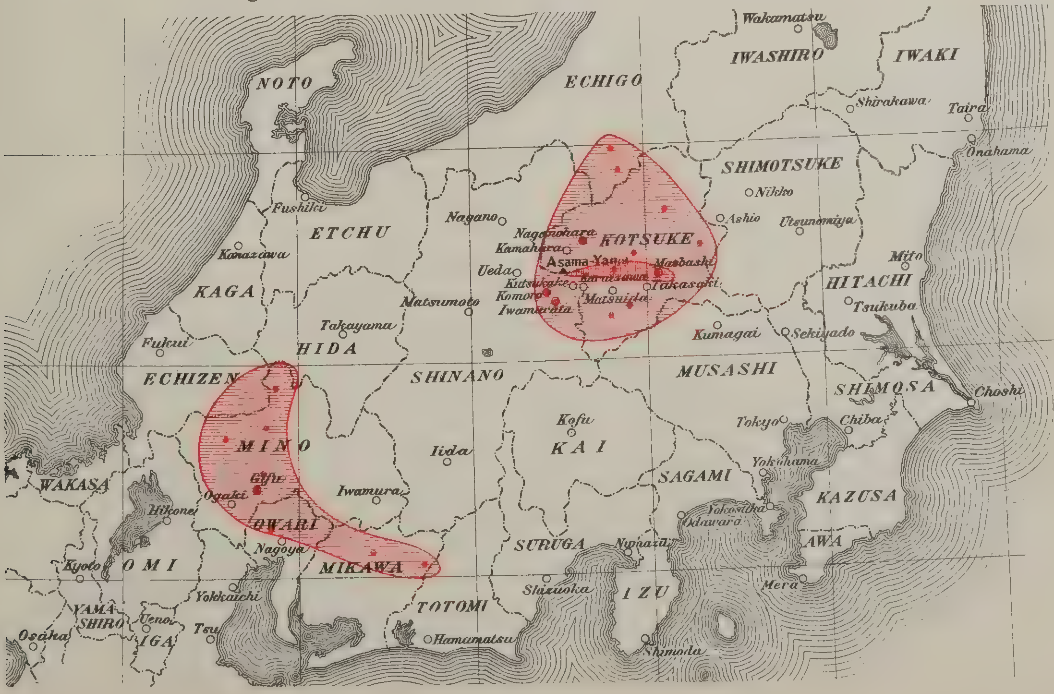


Fig. 32. June 26th, 1913, at 8. 09. 40 a.m.



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Sound Area and Ash-Precipitation Zone of Asama-yama Explosions.

Sound Area is shaded *red* (thin). Ash-precipitation Zone is indicated by dotted line.

Fig. 33. May 29th, 1913, at 10. 44. 12 a.m.

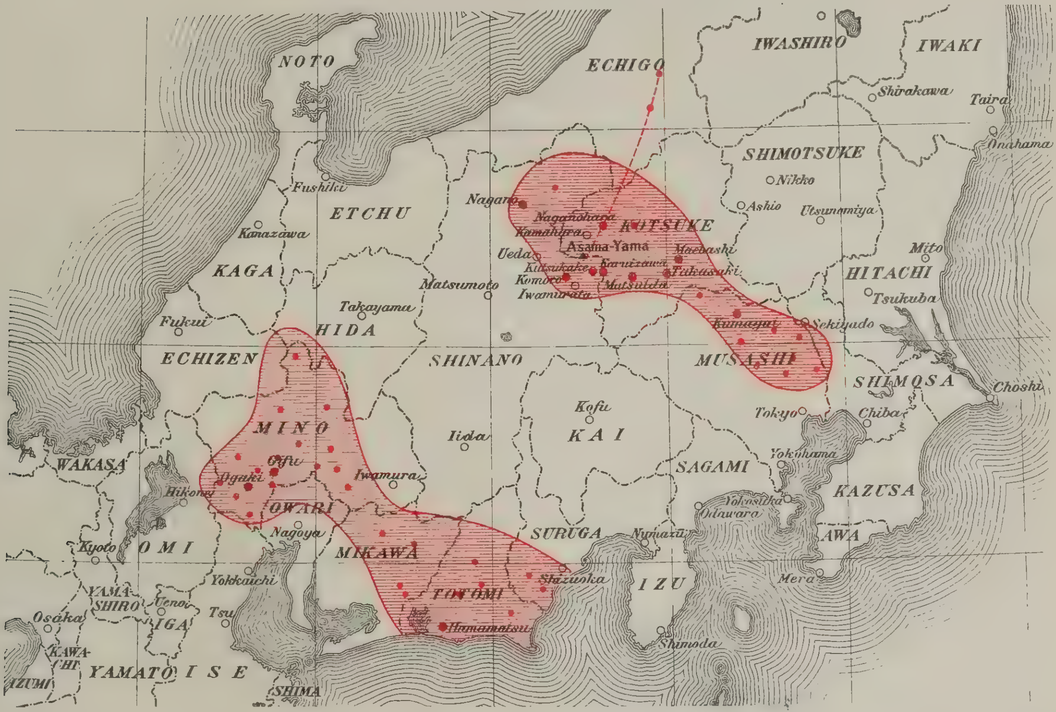

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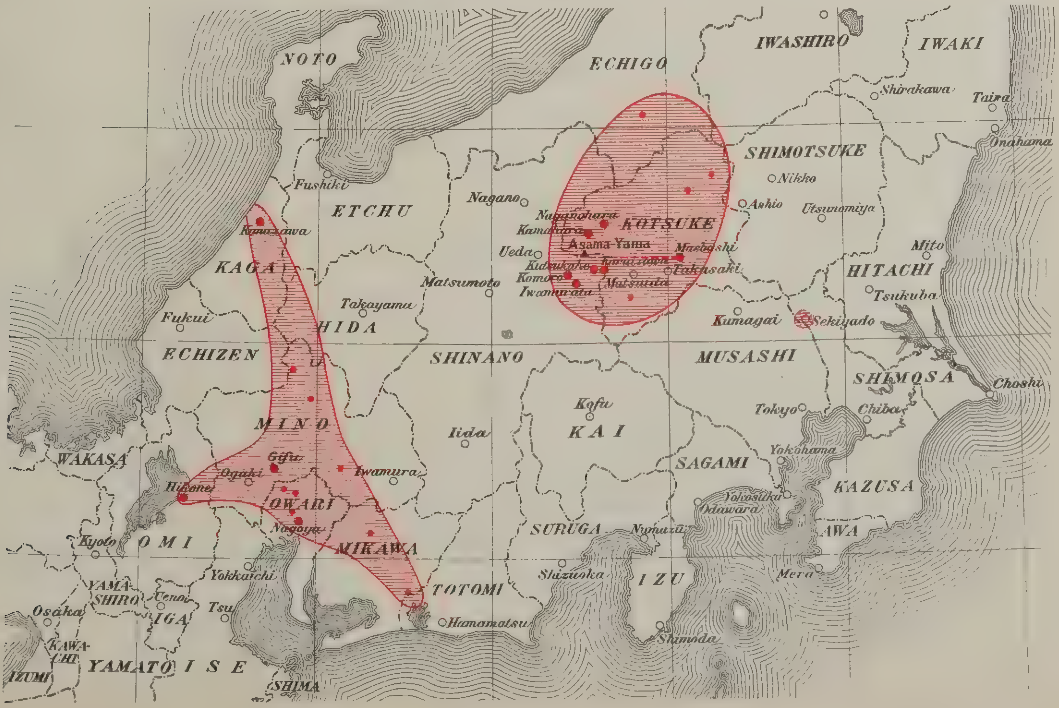
Fig. 34. June 26th, 1913, at 11. 41. 59 p.m.



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Pl. XII.

Sound Area and Ash-Precipitation Zone of Asama-yama Explosions.

Sound Area is shaded *red* (thin). Ash-precipitation Zone is indicated by dotted line.

Fig. 35. Sept. 21st, 1913, at 1. 50. 59 p.m.

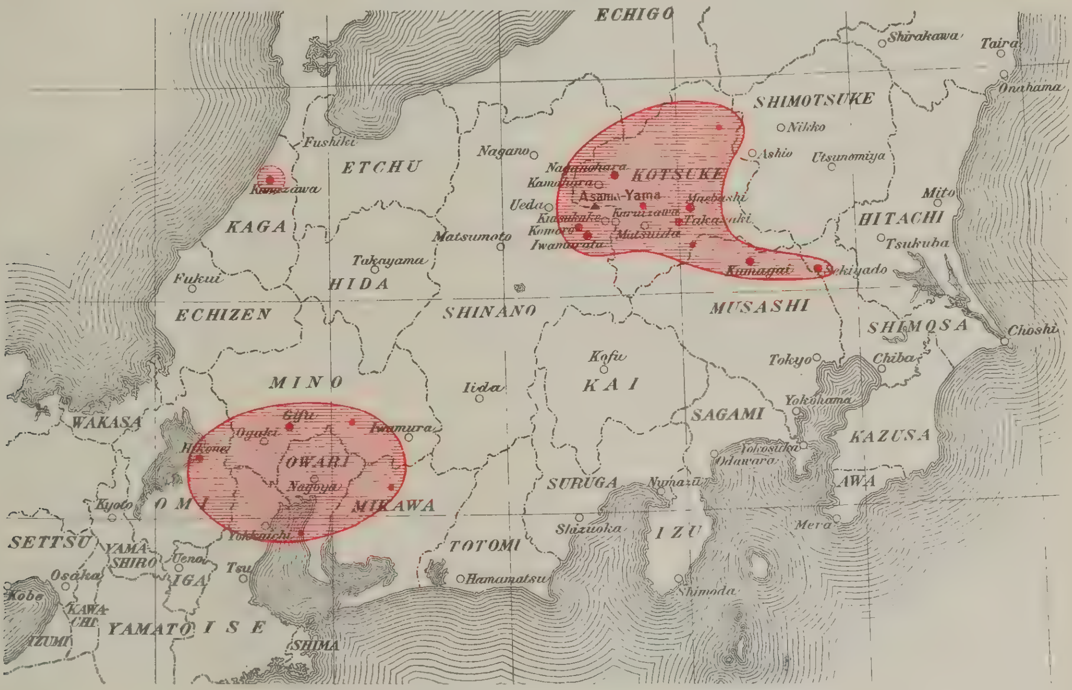

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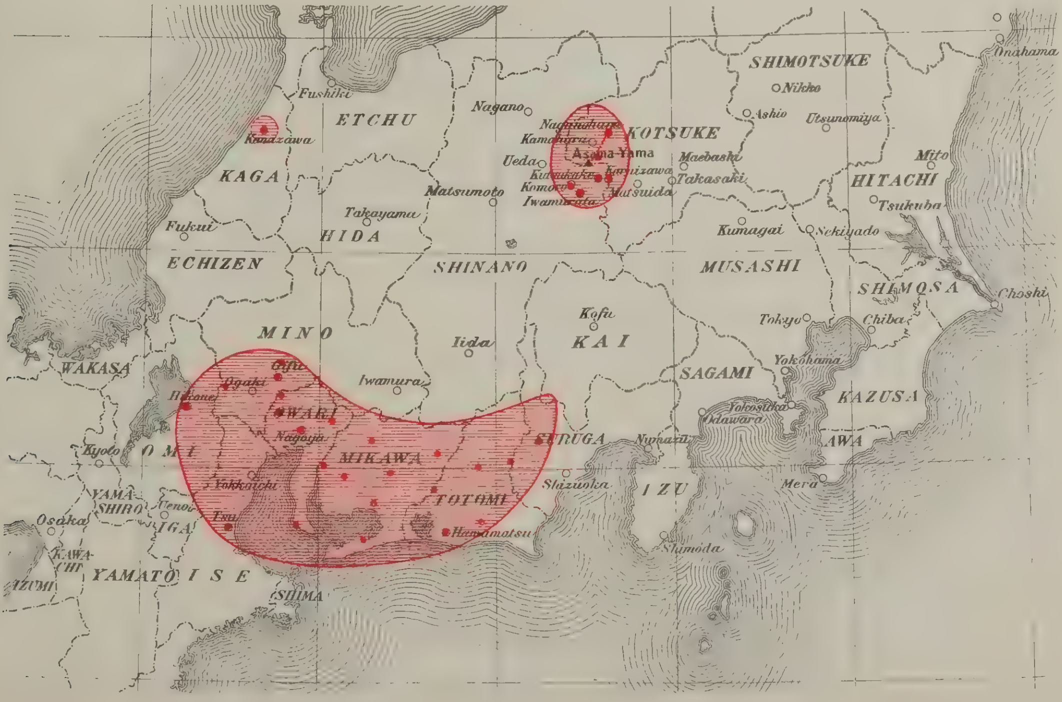
Fig. 36. July 13th, 1913, at 4. 01. 19 p.m.



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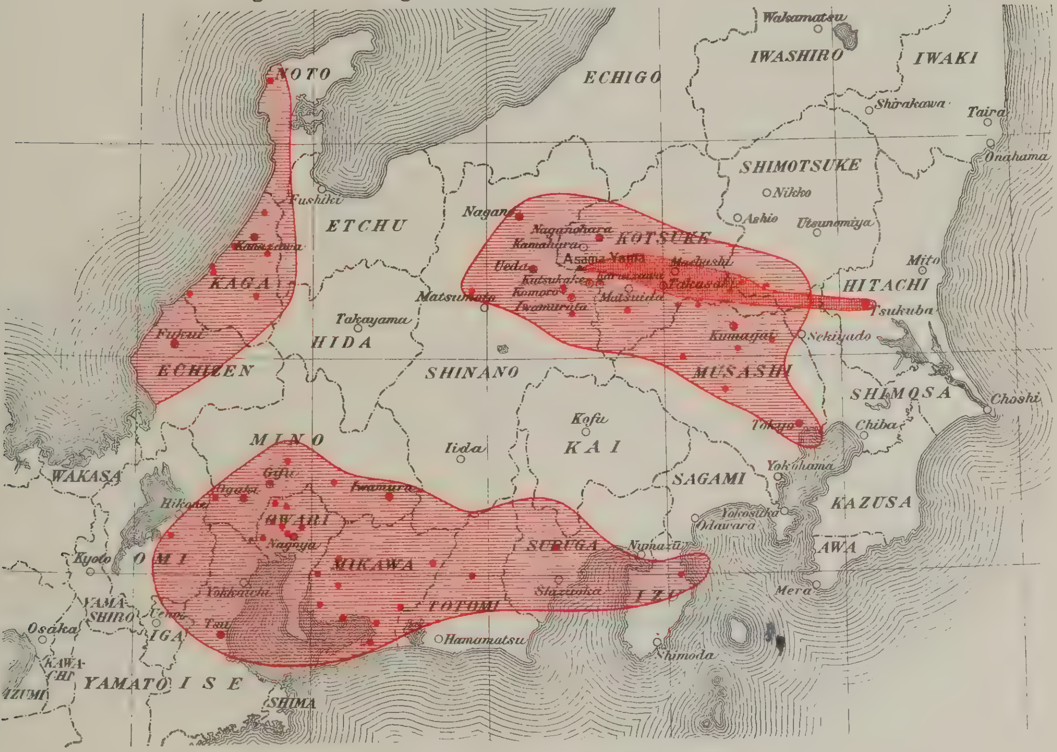
Sound Area and Ash-Precipitation Zone of Asama-yama Explosions.

Sound Area is shaded *red* (thin). Ash-precipitation Zone is shaded *red* (deep).

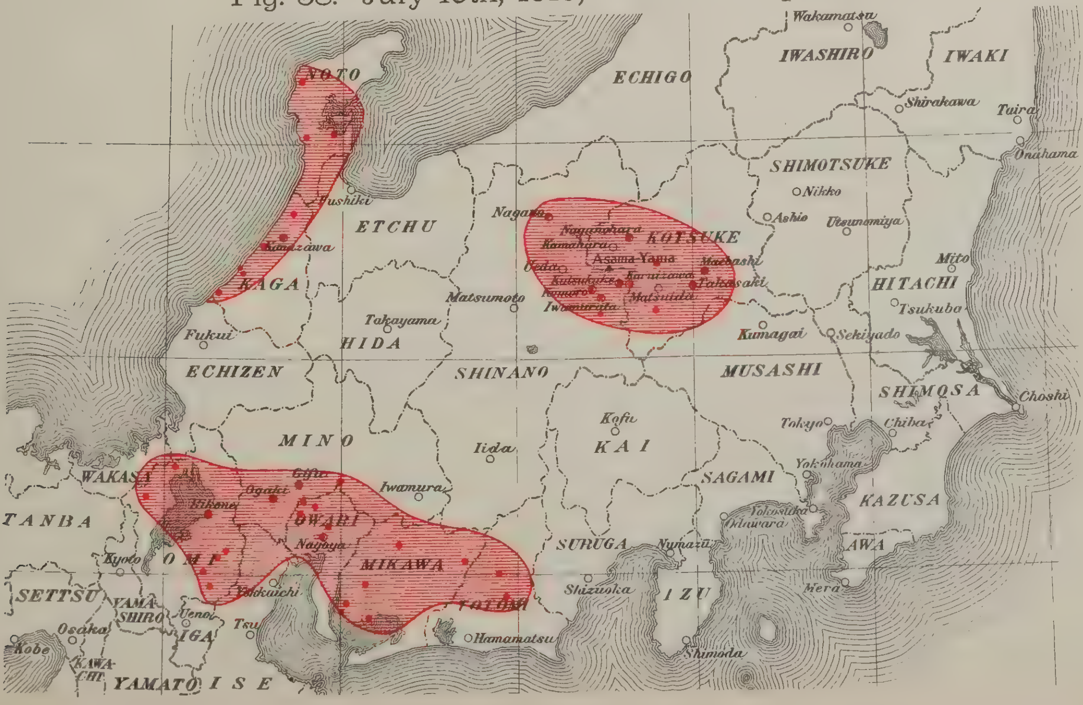
Places where Detonation was perceived are indicated by *red dots.*

Fig. 37. Aug. 12th, 1913, at 11. 20. 33 p.m.



Boundary of Provinces.

Fig. 38. July 19th, 1913, at 0. 54. 03 p.m.



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Sound Area of Asama-yama Explosions.

Sound Area is shaded *red* (thin). Places where Detonation was perceived are indicated by *red dots*.

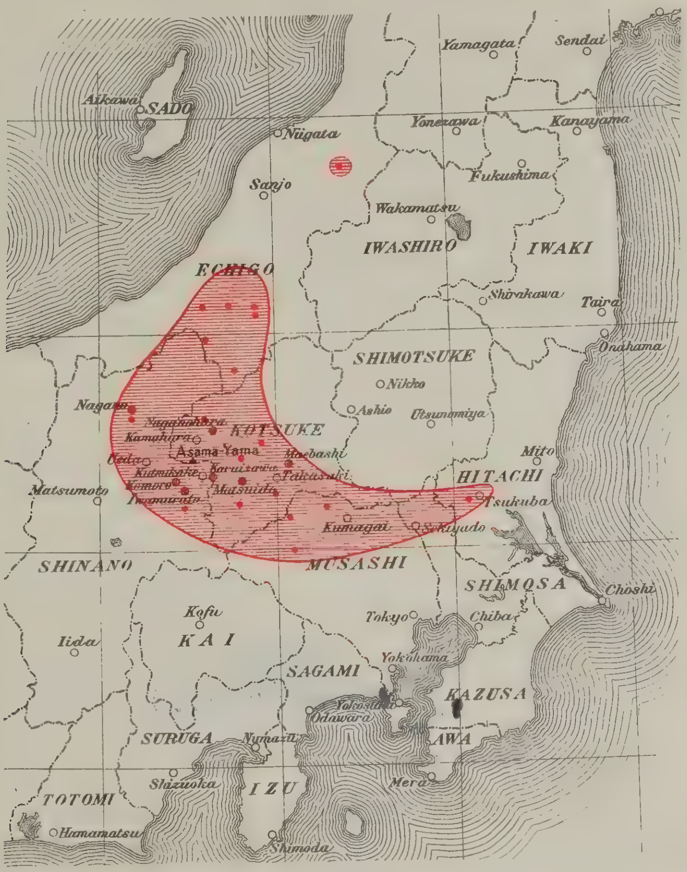

Fig. 39.
Oct. 26th, 1913,
at 3. 14. 38 a.m.

-·-·-·-·-·- Boundary of Provinces.

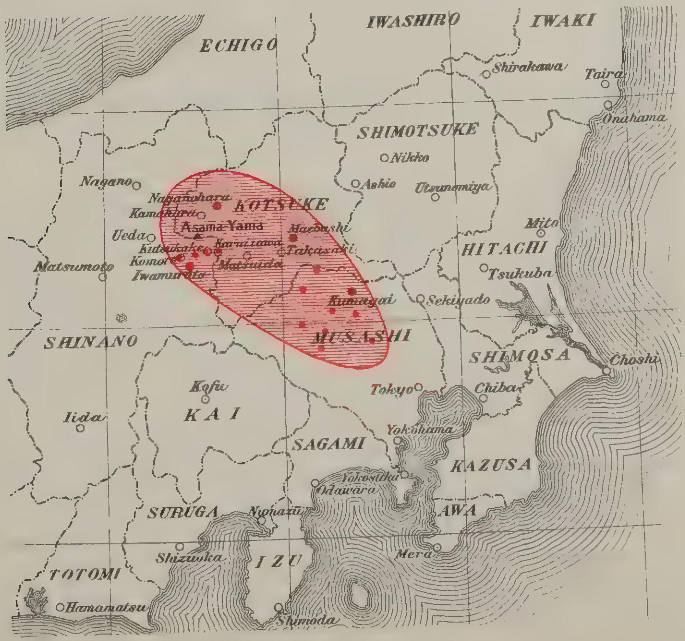

Fig. 40.
May 16th, 1913,
at 4. 41. 00 p.m.

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23. *Explosion of Oct. 26th, 1913, at 3. 14. 38 a.m.* The sound area (Fig. 39) was roughly of a crescent form, which stretched from Mount Tsukuba on the E to the vicinity of the town of Ojiya (Echigo) in the Shinano-gawa valley, including parts of the provinces of Kotsuke, Shinano, Echigo, Musashi, Shimosa, and Hitachi. The radial distances of the sound propagation were 155 km toward the E slightly S, and 104 km toward the NNE. At Maebashi, there was a slight precipitation of ashes. Outside the above mentioned area, the sound was perceived at a place called Shintani-mura, in the H. Kanbara county, Echigo, at a distance of 170 km to the NNE of the Asama-yama. It will be observed that the propagation of the sound in the present case was similar to that of the strong explosion of Oct. 22nd, 1911.

Meteorological Condition. In the early morning of the 26th, the centre of high barometric pressure (774–776 mm) was over Northern China, thence decreasing to 760–765 mm over the Japanese islands. The isobars were arranged nearly parallel to the extension of the latter, and there prevailed northerly or westerly winds at most places in Central and Northern Japan, with the maximum wind velocity of 14.2–9.7 m/s (NW) at Niigata. The air temperature varied at 6 a.m. from 0°.2 to 13°.8 C, with the mean of 8°.9 C. The weather was clear or fair at several places.

TABLE XII. WIND DIRECTION AND VELOCITY, AIR TEMPERATURE, AND CLOUD AMOUNT, AT 2 AND 6 A.M., ON OCT. 26TH, 1913.

Group.	Meteorological Station.	Wind Direction and Velocity (m/s).				Air Temperature.		Cloud Amount.	
		2 a.m.		6 a.m.		2 a.m.	6 a.m.	2 a.m.	6 a.m.
I	Fukushima.	WNW	11.2	NNW	7.2	15°.9 C	13°.0 C	1	5
	Utsunomiya.	—	0.4	NW	1.6	5.5	4.6	0	0
	Mito.	NNW	2.6	NNW	2.2	7.5	6.0	0	1
	Niigata.	NW	14.2	NW	9.7	13.4	13.5	10	10
	Maebashi.	WNW	7.2	N	4.9	9.5	8.2	0	1
	Choshi.	W	2.0	NW	1.6	12.7	11.7	3	10
	Kumagai.	WNW	3.2	ESE	0.7	8.0	6.8	0	4
	Tokyo.	NNW	2.4	NW	2.0	9.5	8.8	0	10
	Yokohama.	NNE	0.7	NNE	2.7	10.9	9.4	1	10
	Kofu.	NW	0.5	NW	1.0	5.4	5.2	0	10
	Nagano.	E	1.0	NW	1.4	5.6	5.3	10	10
	Matsumoto.	S	0.9	W	1.8	1.6	0.2	0	0
	Iida.	—	0.3	E	1.1	3.8	1.7	0	3
II	Numazu.	ENE	1.7	ENE	4.5	9.4	9.4	0	10
	Hamamatsu.	WSW	3.6	W	4.5	14.0	13.8	2	9
	Gifu.	ENE	1.0	N	3.5	9.8	9.0	2	1
	Fushiki.	SSW	2.6	N	5.3	11.6	13.3	10	10
	Nagoya.	NNW	2.9	NNW	3.6	10.5	9.8	9	0
	Hikone.	S	1.9	S	1.8	9.1	9.1	1	2
	Fukui.	ESE	2.3	NE	1.0	10.6	10.1	0	10
	Kanazawa.	SSW	5.0	ENE	5.6	13.8	12.7	9	10
	Takayama.	—	0.2	—	0.0	1.9	3.0	0	10
	Tsu.	W	6.1	WSW	3.3	11.5	10.1	0	0

24. Relation between sound area and ash-precipitation

zones.* Among the 12 explosions (§ 10) considered above there were 9 cases, namely, Nos. 3 to 11, in which the sound area was composed of two branches; these having taken place all between May 29th and Sept. 21st, in the year 1913. On the other hand, the three other explosions, 1, 2, and 12, in each of which the detonation was heard only in the eastern branch, occurred respectively on Dec. 14th, 1912, and May 16th and Oct. 26th, in 1913. These facts may indicate the existence in the summer times of the atmospheric conditions over Central Japan favourable for the formation of the western branch of sound area with the zone of silence situated between it and the Asama-yama. It must not, however, be forgotten that the latter phenomenon did also take place in the colder months, as was the case with the explosions of Dec. 16th and 25th, 1910, and of April 3rd, 1911.

From a comparison of the Figs. 29 to 40, we may divide the explosions Nos. 3 to 11 into the following four groups, according to the forms and relative positions of the two branches of the sound area. Group A: Explosions Nos. 4, 7, and 6, or those of June 17th, and of June 26th, at 11 p.m. and at 8 a.m. Group B: Explosion (No. 5) on June 20th. The explosions of Dec. 25th, 1910, and of April 3rd, 1911, also belong to this group. Group C: Explosions Nos. 3, 8, and 11, or those of May 29th, July 13th, and Sept. 21st. The explosion on Dec. 16th, 1910, also belongs to this group. Group D: Explosions Nos. 10 and 9, or those of Aug. 12th and July 19th.

The sound areas of the explosions belonging to each of the different groups are more or less mutually similar, and the position and form of the western branch seem to depend on that of the eastern branch or the extension of the ash-precipitation zone.

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* Descriptions of the sound areas of the Asama-yama explosions in 1909 to 1911 are given in the *Bulletin*, Vol. VI, No. 1. For interesting and valuable discussions on the anomalous sound propagation the reader is referred to Prof. v. d. Borne's paper, "Ueber die Schallverbreitung bei Explosionskatastrophen," Physik. Zeitschrift, 11. Jahrgang, 1910, and to Dr. S. Fujiwara's paper, "On the abnormal propagation of sound wave in the atmosphere," Bulletin of the Central Meteorological Observatory of Japan, Vol. II, 1912.

Explosions of Group A. (Figs. 30, 34, and 32.) In the explosion of June 17th, both the general course of the ash-precipitation zone and the longer extension of the eastern branch of the sound area were nearly from W to E, being approximately normal to, and directed away from, the arc of the western branch. In the case of the explosion of June 26th, at 11 p.m., the extension of the western branch of the sound area was nearly in the same direction as that of the preceding case, the ashes being also carried approximately toward the E. In the explosion of June 26th, at 8 a.m., the ashes were carried also nearly toward the E, and the arrangement of the sound area was not much different from that of the outburst in the evening of the same day, except that the western branch was in the present instance smaller in extension.

Explosions of Group B. (Fig. 31.) In the explosion of June 20th, the western branch of the sound area extended from the N. part of Owari into the Japan Sea on the north, being appreciably displaced northward when compared to those of the outbursts of group A. In correspondence to this fact, both the course of the ash-precipitation zone and the greatest radial extension of the eastern branch of sound area were directed toward the ESE. On the occasion of the explosion of Dec. 25th, 1910, the western branch area was limited to the two provinces of Etchu and Hida and did not extend to Mino and Owari southwards; there having been the precipitation of sand at the Wakasare Cottage at the N. foot of the Ko-Asama, which was also the case with the outburst above considered. Again, in the explosion of April 3rd, 1911, the arrangement of the two branch areas was not much different from that for the latter, although there was no report on the falling of ashes. (See Figs. 27 and 28, in No. 1 of the preceding volume.)

Explosions of Group C. (Figs. 33, 36 and 35.) In the two explosions of May 29th and July 13th, the ashes were carried in the NNE direction to the town of Naganohara or further to the SE part of the province of Echigo. Consequently the western branch of the sound area was in each case shifted much south-eastwards and extended from the vicinity of Lake Biwa to the west part of the province of Suruga. The explosion of Dec. 16th, 1910, (Fig. 24, in Vol. VI, No. 1, of the Bulletin), furnished a case analogous to the two outbursts here considered; the ashes having been carried toward the NNE to Naganohara, although the eastern branch sound-area extended eastwards to the Pacific coast. To the S and SW from the Asama-yama, the detonation was, on the occasion in question, heard in the western branch area stretching in the EW direction and composed of the city of Nagoya and the vicinity, the N. part of Mikawa, and the S. extremity of Kai. In the explosion of Sept. 21st there was a precipitation of ashes and small flat lava fragments at the Wakasare Cottage and at the Asama Pasture Ground to the ENE of the volcano. Consequently we find, in the opposite direction, the western branch area extending over parts of Owari, Mino, etc.

Explosions of Group D. (Figs. 37 and 38.) In the explosion of Aug. 12th, both the course of the ash-precipitation zone and the extension of the eastern branch of the sound area were directed toward the ESE, approximately normal to the N. division of the western branch. It may be that the latter was continued for some distance northwards over the Japan Sea and formed, together with the S. division a great arc similar to, or larger than, the western branch of the explosion of June 17th, which was also very nearly separated into the N and S pieces by the existence of a non-perception tract in Mino. On the occasion of the outburst of July 19th, the ashes were carried south-eastwards from the volcano, in which consequence, probably, the N. and S. divisions of the western branch area were shifted slightly toward the N or NW. It is to be remembered that the two explosions here considered were very violent, being not much inferior to the strong eruption of June 17th.

The facts described above seem to point to the following two conclusions:—(i). The course of the ash-precipitation zone approximately forms a sort of middle axis, about which the eastern branch of the sound area is more or less symmetrical, as is illustrated in the cases of the explosions of June 17th and 20th, and of Aug. 12th, in which the ashes were carried to a sufficiently long distance from the volcano. (ii). The western branch of the sound area, or more strictly its central part, is located in the direction opposite to the course of the ash-precipitation zone*, such that its position is shifted to different azimuths between the SW and W with respect to the Asama-yama, although the radial distance may not greatly vary.

25. ***Eastern branch of sound area and wind direction.*** The dependence of the eastern branch of the sound area on the direction of the ash-precipitation zone, which was clearly indicated already by the three strong outbursts of Dec. 7th, 1909; Dec. 2nd, 1910; and May 8th, 1911, is evidently due to the wind prevailing at the higher atmospheric region; the surface winds having, as will be seen from §§ 11 to 23, no definite relation on the propagation of the sound or the transportation of the ashes. The direction of the latter varied from NW→SE to SSW→NNE, and was on the average toward the E, as follows:—Toward the E, three cases; toward the SE, one case; toward the ESE, three cases; toward the ENE, one case; and toward the NNE, three cases. This conclusion is of course in accordance with the results found from the examination of the former eruptions of the Asama-yama. That the mean direction of the ash-precipitation zone is identical with that of the higher air current is evident from an inspection of Table XIII, which gives the mean direction of motion of the upper cloud observed during the 5 years between 1906 and 1910 at the different meteorological stations in Central Japan.

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* This fact seems to have been in a measure anticipated by Dr. S. Fujiwara. In the Bull. Cent. Met. Obs. Japan, Vol. II, p. 59, be says "....the range and the direction of the silent region may vary in every case,....."

TABLE XIII. MEAN RESULTANT DIRECTION OF WIND AND THE MEAN DIRECTION OF UPPER CLOUD.

Meteorological Station. (I)	Mean Resultant Wind Direction.	Upper Cloud.	Meteorological Station. (II)	Mean Resultant Wind Direction.	Upper Cloud.
Fukushima.	N 25° W	S 86° W	Numazu.	N 86° E	S 85° W
Utsunomiya.	N 77° E	S 86° W	Hamamatsu.	N 55° W	W
Mito.	N 12° E	S 58° W	Gifu.	N 30° W	N 87° W
Niigata.	S 24° W	S 81° W	Fushiki.	S 71° W	S 83° W
Maebashi.	N 14° W	W	Nagoya.	N 45° W	S 88° W
Choshi.	N 14° E	S 83° W	Hikone.	N 31° W	N 86° W
Kumagai.	N 39° W	N 89° W	Fukui.	S 25° W	S 85° W
Tokyo.	N 8° W	S 83° W	Kanazawa.	S 78° E	S 81° W
Yokohama.	N 11° W	N 89° W	Takayama.	N 43° W	N 88° W
Kofu.	S 53° W	S 84° W	Tsu.	N 59° W	S 88° W
Nagano.	N 45° W	S 81° W			
Matsumoto.	S 73° W	S 89° W			
Iida.	S 72° W	S 81° W			

The height of the upper cloud, whose mean direction of motion is, according to the above table, from W to E, varies from a few km probably up to about 10 km above the sea level. The smokes and ashes darted upwards by the strong explosions of the Asama-yama, whose height of ascent varies from about 5 km to 10 km (§§ 4 and 11), will be caught and carried eastwards by the westerly wind in the higher region, whose direction is essentially constant all the year round.

Fig. 41.

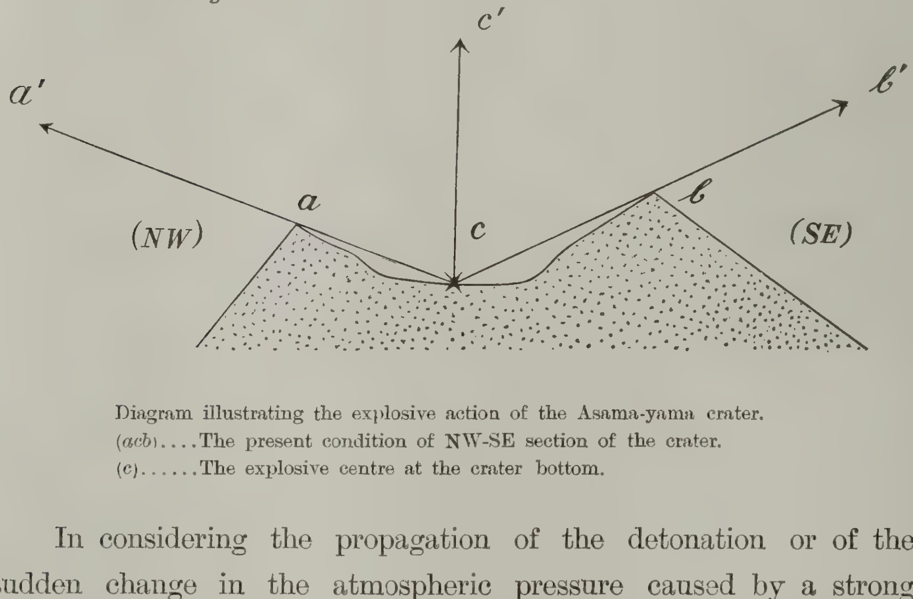
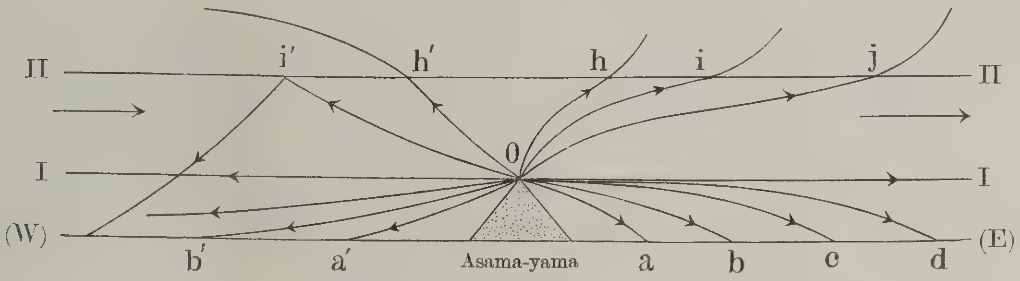


Diagram illustrating the explosive action of the Asama-yama crater.
(*acb*)....The present condition of NW-SE section of the crater.
(*c*)......The explosive centre at the crater bottom.

In considering the propagation of the detonation or of the sudden change in the atmospheric pressure caused by a strong explosion, it must be remembered that the principal effect will be spent upwards. Thus, in the annexed diagram, the greatest force of the detonation or air concussion must be in the vertical direction CC', the boundary of the violent action being approximately formed by the conical surface $a' \ c \ b'$, connecting the explosion centre (C) of the crater bottom with the rim of the latter. This boundary surface, outside or below which the detonation will be perceived with a comparatively small intensity, may be supposed for 1912 and 1913 to be represented by the horizontal plane through the top of the Asama-yama, as the actual crater was quite shallow in these two years.

Now to examine the formation of the eastern branch of the sound area, let us suppose I I (Fig. 42) to be the plane last mentioned, namely, that drawn at an altitude of about $2\frac{1}{2}$ km, the elevation of the volcano. Further let II II be the plane drawn horizontally at a height of some 10 km, such that the space between it and the plane I I is approximately the region of the upper cloud, in which prevails the westerly wind whose velocity (v) increase with the altitude probably to about 40 or 50 m/s. Below the plane I I, the westerly wind gradually decreases in velocity with the descent. Under these conditions, the detonation will reach the tract to the east of the Asama-yama by the paths below the plane I I, namely, *a*, *b*, *c*, *d*, etc., which are curved downwards, and thus give a condensation in the density of the sound rays. On the other hand, at the western foot of the mountain, there will be also the sound rays below the plane I I, namely, *a*′, *b*′,....which, being

Fig. 42. Diagram illustrating the propagation of the Asama-yama Detonation.



(I I)....Horizontal plane through the top of Asama-yama.
(II II)....Upper boundary of the layer of the greatest westerly wind.
(*b*′*a*′....*cd*)....Ground level. Arrows indicate the westerly wind.
O....crater.

curved upwards, will be smaller in the density than on the eastern side. This, coupled with the decrease of the intensity of sound with the increasing radial distance will cause the detonation to be enfeebled and become soon inaudible in the direction against the wind. Thus the "eastern branch" of the sound area, whose formation is due to the *direct* propagation from the volcano, ought not to extend much toward the W, as is almost invariably the case.

26. *Western branch of sound area and higher air current.* To account for the formation of the western branch at considerable distance from the Asama-yama in direction contrary to the course of the ash-precipitation zone, let us assume the existence over the upper boundary of the space of the westerly motion of an atmospheric layer of strong easterly wind. Then the sound rays (h, i, j,....) of the detonation starting upwards or eastwards from the top of the volcano, will be curved eastwards till they meet the plane II II, to be thereafter curved back westwards; the result being that the rays in question will not, under the supposed circumstances, reach down to the ground. This explains why there is no special sound area at a distance to the E (or NE, or SE) of the Asama-yama separated from that enclosing the latter. On the other hand, the sound rays directed westwards (h', i',....) will be at first curved eastwards or upwards, but curved westwards after crossing the boundary plane II II; those (i'....) with sufficiently small angle of incidence being, when combined with the influence of the difference in temperature and density, probably reflected back to the ground and giving rise to the western branch sound area. The space between the base of the mountain and the point of incidence of the reflected rays, where no sound is heard, forms the silent zone.

27. Extensions of two branches of sound area. From Figs. 30 to 38, it will be observed that the eastern branch of the sound area, or the region of audibility about the Asama-yama itself, was sometimes much smaller than that of the western branch, which is separated by a considerable distance from the latter. In the following table I give the areas measured with a planimeter of the two branches in the cases of the 9 explosions in 1913, and of the 3 explosions in 1910 and 1911.

TABLE XIV. COMPARISON OF THE EXTENSIONS (LAND AREAS) OF THE TWO BRANCHES OF THE SOUND AREA.

No. (§ 10)	Date.	Extension (area) of Eastern Branch. (i)	Extension (area) of Western Branch.			Ratio : (ii)/(i).
			N. Division.	S. Division.	Total. (ii)	
		sq. km	sq. km	sq. km	sq km	
4	June 17th, 1913.	25,690	—	—	27,100	1.06
7	„ 26th, „	8,290	—	—	7,460	0.90
6	„ 26th, „	6,840	—	—	5,770	0.84
5	„ 20th, „	9,360	—	—	10,200	1.09
3	May 29th, „	8,130	—	—	11,240	1.39
8	July 13th, „	1,860	—	—	16,390	8.81
11	Sept. 21st, „	7,190	—	—	6,350	0.89
10	Aug. 12th, „	12,330	5,370	18,240	23,610	1.92
9	July 19th, „	6,080	2,720	10,250	12,970	2.13
	Dec. 16th, 1910.	19,000	—	—	5,300	0.28
	„ 25th, „	16,580	—	—	11,020	0.67
	April 3rd, 1911.	4,450	—	—	10,120	2.28
	Mean.	—	—	—	—	1.90

Thus, the land area of the western branch, which had the greatest amounts of 27,100 and 23,610 sq. km respectively in the cases of the explosions of June 17th and Aug. 12th, 1913, was 0.28 to

8.81 times that of the eastern branch, the average ratio being about 2.1. Again the intensity of the detonation perceived at different places in the western branch area seems generally to be well pronounced. Thus, on the occasion of the explosion of July 13th, 1913, whose greatest radius of the direct sound propagation was only about 30 km, the effect was felt, in the city of Nagoya (radial distance=201 km.) as a loud detonation like that of a heavy body fallen on the ground, causing some of the houses to be shaken; while, at the town of Inazawa (radial distance=203 km), the sound was mistaken for an earthquake and some people fled out of doors. The air wave of the explosion of June 26th, 1913, at 11 p.m., was also felt as a loud detonation at the meteorological observatory of Nagoya. The sound of the explosion of July 19th, 1913, was reported to have been violent at the town of Ko-ori (radial distance=193 km) in the province of Owari. Again, in the case of explosion of June 17th, 1913, the sound was perceived at the different places in the province of Hitachi, about 170 km to the E of the Asama-yama, generally as a feeble noise or slight shaking; while, at the meteorological observatory of Gifu, 191 km to the SW of the volcano, there were perceived three successive loud detonations, which shook the doors and *shoji*. On the same occasion, at Mutsumi-mura (radial distance=210 km) in the province of Mikawa, two successive strong sounds were heard, causing some of the people to escape out of doors.

The above-mentioned peculiarities, namely, the large extension of, and the strong intensity of the detonation in, the western branch area admit of an easy explanation, if we remember that the existence of the latter is due to the total reflection of those violent sound rays, which start from the volcano in more or less *upward* directions and become audible at a definite westerly distance without much loss of energy. On the other hand, the sound perceived in the eastern branch area is due to the air waves of secondary force directly transmitted from the origin below the plane through the mountain top and may be enfeebled at a comparatively short radial distance. The places at the foot of the Asama-yama, where the detonation was often of a terrific violence, causing some such slight damage as the breaking of *shoji*, overthrowing of *karakami* (sliding screens) and *to* (sliding doors), or the falling down of *kamoi* (wooden lintels over doorways) due to the strong shakings communicated to the houses, are Karuizawa on the E, Iwamurata on the S, Oi-mura on the SE, and Naganohara on the N, within the limiting distance of about 20 km from the crater.

28. *Cases of non-existence of western branch.* The extension of the sound areas in the cases of the explosions in 1913 and in the preceding years, in which the western branch did not exist, was as follows:—

Group.	Date.	Extension of Sound Area.
A	Dec. 7th, 1909.	71,800 sq. km.
	Dec. 2nd, 1910.	60,700
	May 8th, 1911.	62,900
B	Dec. 14th, 1912.	32,900
	May 31st, 1909.	7,370
	Dec. 15th, 1910.	12,100
	Jan. 18th, 1911, (5⅓ p.m.)	6,230
	„ „ „ (9½ p.m.)	20,000
	Oct. 22nd, 1911.	28,100
	May 16th, 1913.	7,240
	Oct. 16th, „	14,500

Group A includes the cases in which the sound area were extensive and greater than 6,000 sq. km, while Group B includes those of smaller extension. Thus, the western branch did not come into existence, amongst the others, when the eastern branch, or area of direct sound propagation was large enough. It would seem that the prevalence of the too strong westerly winds prevents the formation of the western branch sound area, tending to give steeper angle to the sound rays emanating westwards and thereby causing them to proceed on without being reflected back to the ground.

29. ***Distribution of sound frequency.*** Figs. 43 and 44 indicate the relative frequencies with which the Asama-yama detonations were heard at the different places, each being the results of the superpositions of the sound areas of a number of the strong explosions. Thus Fig. 43 relates to the 11 explosions in 1912 and 1913 (Nos. 2 to 12, § 10) and the 8 in 1909 to 1911, namely, those on May 31st, 1909; on Dec. 15th, 16th, and 25th, 1910; and on Jan. 18th, (at 5. 20. 58 and 9. 27. 49 p.m.), April 3rd, and Oct. 22nd, 1911. Fig. 44 relates, on the other hand, to the eruption of Dec. 14th, 1912, and the three special outbursts on Dec. 7th, 1909; Dec. 2nd, 1910; and May 8th, 1911; in each of these cases the sound area having notably extended to the NE from the mountain.*

From Fig. 43 it will be noticed that the sound was heard most frequently, on the E. or around the mountain, in an oval area stretching to the E slightly S; the approximate mean radius of the sound area at the NW, W, and SW sides being about 50 km. Off in the west the sound was heard most frequently along an arcual zone stretching from the S part of Noto to the

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* The sound areas of the different explosions in 1909 to 1911 are given in the Bulletin, Vol. VI.

Fig. 43. Sound Areas of the 19 Strong Asama-yama Explosions in 1909-1913.

The curves are the mean lines of equal sound frequency, indicated by the respective numbers.

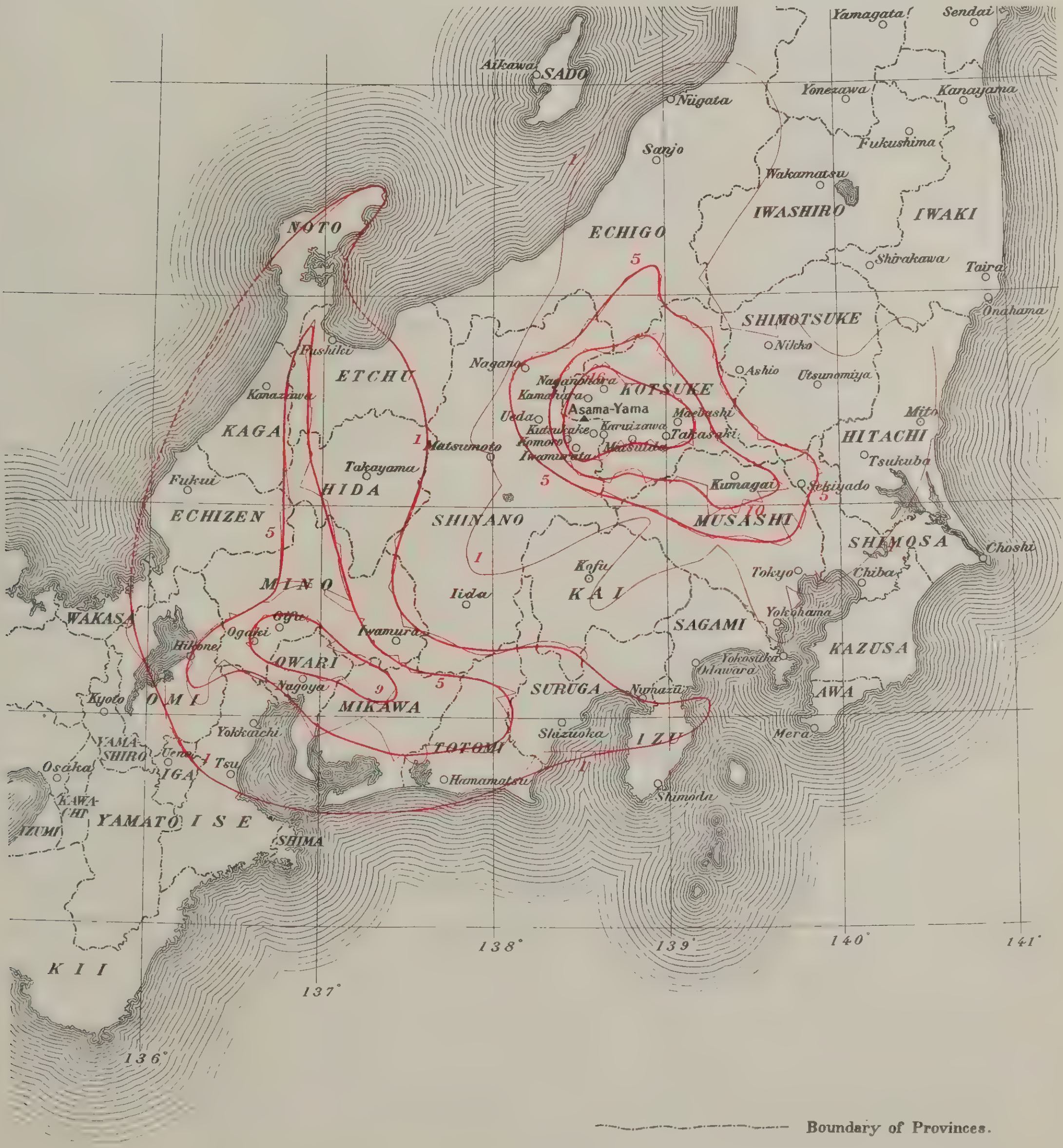

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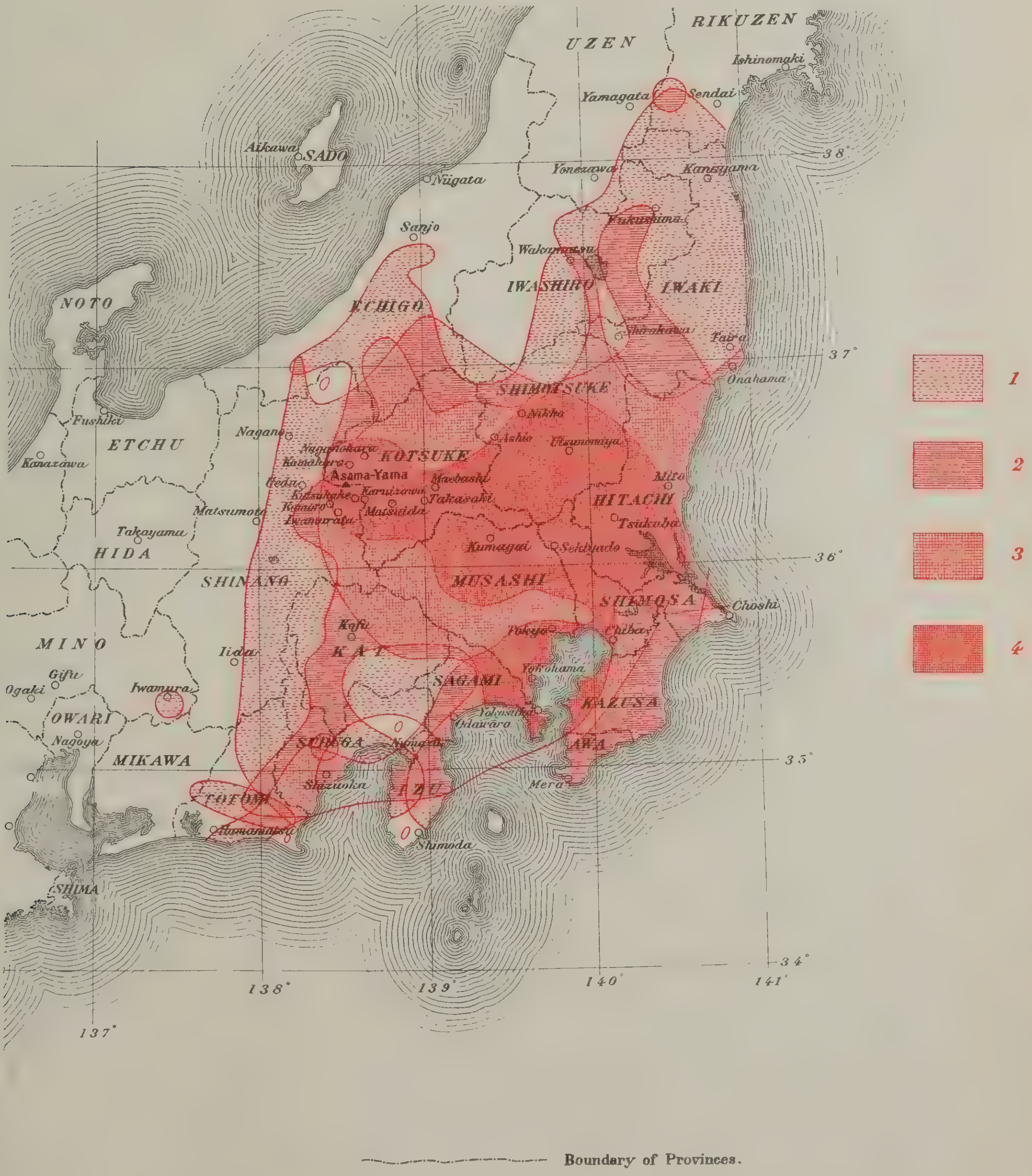
Fig. 44. Sound Areas of the 4 Strong Asama-yama Explosions on Dec 7th, 1909; Dec. 2nd, 1910; May 8th, 1911; and Dec. 14th, 1912.

The four frequencies of 1, 2, 3, 4 are indicated by different red shades. (0)....No sound heard.



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W. part of Suruga, at an average radial distance of about 170 km, whose central part is to the S 45° W from the Asama-yama. The approximate mean value of the internal (concave side) radius of the western branch sound area, which is of a crescent from, is about 130 km, while its maximum external (convex side) radius is about 270 km.

From what has been said above, it will be seen that the zone of silence is bounded by two nearly concentric arcs at the mean distances respectively of 50 and 130 km from the volcano. This conclusion is to be regarded as applicable to the majority of the Asama-yama explosions, and requires a modification for the cases of the outbursts with specially extensive sound areas, namely, those taken into consideration in the construction of Fig. 44, for which the detonation became audible in a part of the silence zone indicated in Fig. 43.

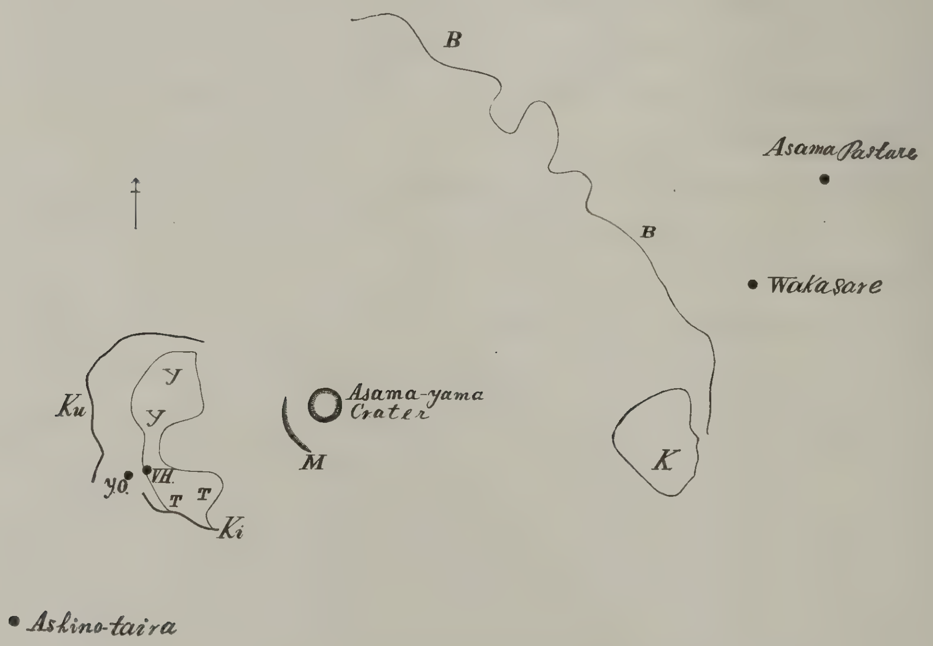
The greatest distance of propagation of the audible sound of the Asama-yama explosions was about 276 km to the NE and 290 km to the SW.

30. ***Repetition of sounds.*** In the cases of the strong explosions in 1913, the detonation was each time repeated twice or thrice at several places scattered throughout the western branch area, which is thus to be regarded essentially as a multiple-sound region. This fact is supplementary to the discussion respecting the 2–sounds and 3–sounds propagations given before, (the *Bulletin*, Vol. VI, p. 76), and it is interesting that the mean radius of the inner boundary of the western branch area (=130 km) is approximately equal to the distance (=120 km) of the boundary of the 2 and 3 sounds zones to the east of the Asama-yama. To the E, N, and S from the volcano the repetition of sounds occurred, in 1913, only at a few places in the province of Kotsuke and Echigo.

CHAPTER III. SEISMOGRAPHICAL OBSERVATIONS OF ASAMA-YAMA ERUPTIONS.

31. *Seismographical observations.* In Chapters IV to IX, I give the descriptions of the instrumental records of the strong Asama-yama eruptions in May 1913 to May 1914, and also those of a number of the small outbursts, of the volcanic micro-tremors, etc., in 1911-1913, observed at the three stations of Yuno-taira, Ashino-taira, and the Asama Pasture Ground, whose relative positions are indicated in the accompanying figure.

Fig. 45. Plan of the Upper part of the Asama-yama.



		Y.O.	Yumo-taira Observatory.
		V.H.	"Volcano House."
M.	Maikake-yama (Remnant of the 2nd Epoch Crater Ring).		
Ku. Ki.	Kurofu-yama Kiba-yama } („ 1st „).		
K.	Ko-Asama, a parasitic cone.	B B	NE Base of the Asama-yama.
Y Y	Flat Ground of Yuno-taira.	T T	Flat Ground of Tengu-no-roji.

The Yuno-taira seismological observatory, whose front points toward S 20° E, is at a horizontal distance of 2,300 m to S 70° W from the crater centre; the top of the Asama-yama, being just screened from view on the Komoro, or south-western, side by the Maikake-yama. The temporal station of Ashino-taira was at a horizontal radial distance of 4,850 m to the S 55° W. These two places, both situated on the SW slope of the volcano, are at the height differences respectively of 580 and 1,130 m below the mouth level of the crater. The Asama Pasture Ground, which is at a horizontal distance of about 6,350 m to the N 65° E from the crater centre, is situated about 1,300 m below the level of the latter, on the Rokuriga-hara, the extensive plateau at the N base of the volcano. From the figure it will be seen that the Yuno-taira observatory and the Asama Pasture Ground are almost exactly on the mutually opposite sides of the crater, the ratio of their radial distances being roughly 1:3. Again, the position of Ashino-taira is not much out of the prolongation of the line joining the Asama Pasture Ground with Yuno-taira.

It is hereby to be noticed that Ashino-taira and Yuno-taira are separated from the present Asama-yama crater by the interposition of the Maikake-yama to the SW of the latter; while there is no sort of barrier on the E, NE, and N sides, so that the Asama Pasture Ground is situated directly at the base of the steep NE slope of the volcano.

The seismological instruments* used in 1912-1914 at the Yuno-taira observatory were: (1), a single component horizontal tromometer of 150 (or 200) times magnification and of the natural oscillation period of 15 to 17 sec., set up for the registration of the *apparent* longitudinal component, or the movements of the ground parallel to the radial direction; (2), a portable two-components horizontal tremor-recorder of 100 times magnification, and of the natural oscillation period of about 4 sec. oriented for the registration of the *apparent* longitudinal and transverse movements, or those respectively parallel and normal to the radius; and (3), a vertical motion seismograph of 50 times magnification and of the natural oscillation period of 10 sec. At Ashino-taira and the Asama Pasture Ground the observation was made only with portable tremor-recorders, of magnifications respectively of 100 and 200, put up so as to register for each place the apparent longitudinal and transverse components of the earthquake motion with respect to the crater centre.* The times of occurrence at Yuno-taira of the eruptions in 1913 were carefully determined from the instrumental records, the error of the time keeper there having been frequently determined by comparisons with pocket chronometers brought from Tokyo, facilitated by the establishment of a telephonic communication between the observatory and the town of Komoro at the SW base of the mountain. The introduction since 1913 of an electrical arrangement, by which the small writing indices of the two component pointers of the tremor-recorders were simultaneously lifted for the interval of 0.5 sec. every full minute, enabled an accurate identification of a given time instant in the two rectangular directions. All the seismographical measurements given in the following pages relate to the horizontal motion alone,** as the vertical component was always very small.

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* See p. 150 of the Bulletin, Vol. VI, No. 2.

For the convenience of the examination, the seismographical diagrams of the different strong eruptions, as well as the more important of the small ones, volcanic micro-tremors, etc., have been photographically enlarged 3 to 20 times, resulting in the total magnification of up to about 4,000 times. (See Figs. 49 to 61.)

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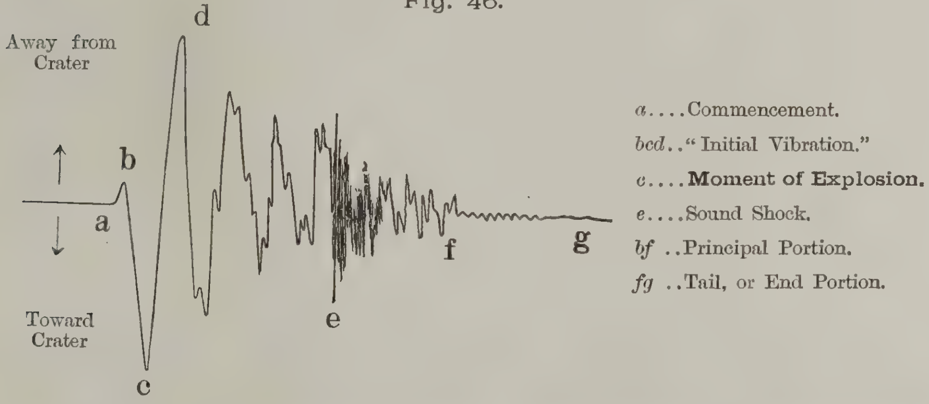
* See also § 1.

** Only for the explosion of May 29th, 1913, the vertical component record is given (Fig. 52).

32. ***Seismograms.*** The longitudinal component seismogram of a strong Asama-yama *explosion* observed at Yuno-taira or the Asama Pasture Ground begins with a very small preliminary motion, *ab* (Fig. 46), directed outwards, corresponding to the preliminary tremor in ordinary cases. Then follows a slow well defined vibration, *bcd*, of period of 2 sec. or so, composed of the 1st displacement, *bc*, directed toward the crater, and the 2nd, or counter, displacement, *cd*, directed away from it. This may be regarded as the first stage of the earthquake motion proper caused by the explosion, and may accordingly be termed the "initial vibration." As explained in Vol. VI, of the Bulletin, the effect of a strong internal explosive force, which leads to the breaking off of the surface lava layer in the crater bottom, is to push upwards the mountain top; the surrounding ground being, in consequence, first drawn toward the crater, to be moved back, or away from it, at the occurrence of the outburst. Hence, the point *c*, namely, the end of the 1st and the commencement of the 2nd displacement

Fig. 46.



of the "initial vibration" may be regarded as corresponding to the *actual moment of the explosion*, an assumption which is found to be satisfactory in the consideration of the sound velocity.

The preliminary portion is longer in duration in the transverse component, than in the longitudinal; while, in the cases of the non-explosive eruptions, it may sometimes reach a considerable length in both components.

The shakings of the ground caused by the strong explosions in 1913 *were not actually sensible* even at the Yuno-taira observatory, where the outbursts were in each case announced to the observer first by the loud detonation, or sound-shock, whose arrival there was several seconds after the preliminary portion and "initial vibration" had been registered by the tromometer. At the temporal station of the Asama Pasture Ground, the time difference in question was longer and the sound-shock was indicated often very clearly by the appearance on the diagram of a series of quick vibrations, as at *e* in the accompanying figure. The effect of the detonation on barographs is considered in a later Chapter.

What may be regarded as the end portion, or tail, of the earthquake motion caused by a strong explosive or non-explosive eruption is usually abruptly smaller than the *principal portion*, which latter is probably to be taken as corresponding to the course of the outburst itself.

In the descriptions of the seismographic records of the Asama-yama eruptions and earthquake shocks, 2a and T are used to designate respectively the double amplitude, or range of motion, and the complete period of the vibration.

33. ***List of Asama-yama disturbances.*** The different typical seismograms considered in Chapters IV to IX, are as follows.

CHAPTER IV. STRONG EXPLOSIONS OBSERVED AT THE ASAMA PASTURE GROUND. (1913.)

(1) Sept. 21st; 1. 50. 59 p.m.
(2) Oct. 7th; 11. 32. 32 a.m.
(3) ,, 15th; 10. 43. 13 p.m.
(4) Oct. 17th; 3. 27. 47 p.m.
(5) ,, 22nd; 3. 55. 42 a.m.
(6) Nov. 14th; 11. 11. 55 ,,

CHAPTER V. STRONG EXPLOSIONS OBSERVED AT ASHINO-TAIRA. (1913).

(1) Sept. 21st.*
(2) Oct, 9th; 1. 09. 10 a.m.
(3) ,, 15th.*
(4) Oct. 17th.*
(5) ,, 22nd.*

CHAPTER VI. STRONG EXPLOSIONS OBSERVED AT YUNO-TAIRA.

(1) May 16th, 1913; 4. 41. 00 p.m.
(2) ,, 27th, ,, 5. 22. 57 a.m.
(3) ,, 29th, ,, 10. 44. 12 ,,
(4) June 13th, ,, 11. 01. 16 p.m.
(5) ,, 17th, ,, 10. 47. 41 ,,
(6) ,, 18th, ,, 6. 21. 03 a.m.
(7) ,, 20th, ,, 4. 06. 47 ,,
(8) ,, 24th. ,, 11. 37. 34 ,,
(9) ,, 26th, ,, 8. 09. 40 ,,
(10) ,, ,, ,, 11. 41. 59 p.m.
(11) July 7th, 1913; 7. 10. 32 a.m.
(12) ,, ,, ,, 9. 46. 53 p.m.
(13) ,, 8th, ,, 5. 25. 25 a.m.
(14) ,, 13th, ,, 4. 01. 19 p.m.
(15) ,, 18th, ,, 2. 08. 34 a.m.
(16) ,, 19th, ,, 0. 54. 03 p.m.
(17) Aug. 12th, ,, 7. 45. 08 ,,
(18) ,, ,, ,, 11. 20. 33 ,,
(19) May 5th, 1914; 0. 33. 02 a.m.

CHAPTER VII. LARGE NON-EXPLOSIVE ERUPTIONS OBSERVED AT YUNO-TAIRA OR THE ASAMA PASTURE GROUND. (1913.)

(1) June 24th; 11. 34. 17 p.m.
(2) July 1st; 0. 17. 01 ,,
(3) Aug. 13th; 4. 01. 19 ,,
(4) ,, 15th; 9. 59. 11 a.m.
(5) Aug. 15th; 3. 58. 46 p.m.
(6) ,, ,, ; 5. 08. 54 ,,
(7) Nov. 20th; 3. 40. 35 ,,

CHAPTER VIII. VOLCANIC MICRO-TREMORS AND SMALL NON-EXPLOSIVE ERUPTIONS OBSERVED AT YUNO-TAIRA.

(i) Volcanic Micro-tremors and Eruptions on Oct. 2nd, 1912.
(ii) *Small Eruptions in* 1911:—
(1) July 1st; 11. 32. 08 a.m.
(2) ,, 2nd; 2. 18. 23 p.m.
(3) July 8th; 10. 16. 04 a.m.
(4) ,, 14th; 4. 32. 26 ,,

(5) July 21st; 10. 47. 40 p.m.
(6) Aug. 15th; 4. 42. 50 a.m.
(7) „ 20th; 3. 38. 59 „
(8) Aug. 29th; 8. 35. 53 p.m.
(9) Sept. 9th; 11. 49. 21 a.m. and 11. 49. 59 a.m.

(iii) *Small Eruptions in* 1912 :—

(1) July 1st; 5. 33. 50 p.m.
(2) „ 2nd; 5. 30. 07 a.m.
(3) Aug. 3rd; 7. 20. 58 p.m.
(4) „ „ ; 7. 51. 03 „
(5) Aug. 7th; 8. 14. 48 a.m.
(6) „ „ ; 9. 43. 13 „
(7) „ 22nd; 5. 25. 50 „
(8) „ 23rd; 3. 14. 01 p.m.

The tromometer observations in Tokyo of the Asama-yama eruptions are considered in a later Chapter.

CHAPTER IV. ASAMA-YAMA EXPLOSIONS OBSERVED AT ASAMA PASTURE GROUND.[**]

[TREMOR-RECORDER DIAGRAMS]

34. ***Explosion of Sept. 21st, 1913, at 1. 50. 59 p.m.*** According to the report of Mr. Kawazoe, who witnessed the eruption from Yuno-taira, the detonation was like that of blast of a boisterous wind and lasted 3 or 4 sec. According to Mr. T. Kato, who saw the eruption from the foot of the Ko-Asama the detonation was very loud and like that of a gun discharge; the column of black smokes, which rose vertically high up, being gradually carried towards the NE. Several lava blocks fell to the E and N slopes of the Asama-yama, continuing to throw up vapours for some time. At the Wakasare Cottage there were precipitated platy lava fragments 2 cm in dimension, and at the Asama Pasture Ground those of the size of peas.

Total Duration=4 min. (Fig. 51.)

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[*] Also registered at the Asama Pasture Ground.

[**] The times of occurrence of the explosions on Oct. 7th and Nov. 14th were registered by the tremor-recorder at the Asama Pasture Ground, while those of the 4 others considered in this chapter are the results determined by a similar instrument at Ashino-taira.

Longitudinal component. [Preliminary and principal portions: duration=35.5 sec.] The commencement was perfectly sharp, and the preliminary motion, 0.61 sec. in duration, was directed outwards and was very small, its amount being only 0.0018 mm. The "initial vibration" of T=1.8 sec., was composed of the 1st, or outward, displacement of 0.035 mm (duration=0.66 sec.), and of the 2nd, or inward, displacement of 0.043 mm (duration=1.12 sec.). The latter and the next small vibration may be regarded as together forming a slow motion of 1.84 sec. in duration. Then followed two well-defined large displacements of 2a=0.122 and 0.118 mm respectively, making up the maximum vibration of T=2.56 sec. The next displacement (duration=1.1 sec.) was 0.051 mm in range. So far, during the first 6.9 sec. of the earthquake, the motion was gentle and practically free from the superposition of minute movements. For the next 28.6 sec., the motion was made up of quick vibrations of T=0.25 sec., and of max. 2a=0.031 mm, mixed more or less distinctly with those of T=0.70 sec. and of max. 2a=0.02 mm. During this interval, the pointer of the instrument was thrown into slow movements of T=4.4 sec. (max range=0.035 mm), due to the proper oscillation of the pendulum mass. [Sound Shock]. 17.3 sec. after the earthquake commencement, or 16.1 sec. from the end of the 1st displacement of the "initial vibration," there occurred quite abruptly sharp vibrations, which began with the maximum motion of 0.047 mm and lasted about 2.5 sec. These were evidently due to the arrival of the "sound shock," or the volcanic detonation. [End portion.] The motion was composed of the vibrations of T=0.96 sec. (max. 2a=0.015 mm), mixed with some slower movements, but free from the superposition of quick vibrations.

Transverse Component. [Preliminary and principal portions:

duration=29.2 sec.] For the 1st 2.3 sec., there was practically no motion. Then took place a displacement of 0.0087 mm toward the NW, and there were during the next 11.6 sec., 9 vibrations of T=1.3 sec., grouped into those of double period; the greatest motion (absolute maximum) of 0.058 mm occurring 11.1 sec. after the earthquake commencement. So far, the vibrations were simple and almost entirely free from the superposition of quick movements. The latter began to appear from 13.6 sec. after the earthquake commencement; the motion consisting, for the remaining 15.4 sec., of the vibrations of T=0.29 sec. (max. 2a=0.028 mm), mixed with the slower ones of T=1.0 sec., max. 2a=0.030 mm. [End portion.] The motion consisted principally of vibrations of T=1.03 sec., max. 2a=0.023 mm. [Sound Shock.] The quick vibration of 2a=0.049 mm due to the sound shock occurred 17.2 sec. after the earthquake commencement, simultaneously with the corresponding movement in the longitudinal component.

Comparison of Longitudinal and Transverse Diagrams. The 1st well defined motion in the transverse component occurred 1.7 sec. later than the 1st displacement of the "initial vibration" in the longitudinal component. Again the absolute maximum motion in the transverse component, which was accompanied by no special maximum phase in the longitudinal component, occurred 8.0 sec. later than the large slow vibration in the latter. The times of appearance of the conspicuous quick vibrations in the two directions were separated also by nearly an equal interval, namely, 7.0 sec. The average period of the large vibrations in the earlier part of the transverse component was 1.3 sec., which is equal to half of the period of the maximum motion in the longitudinal component, namely, 2.6 sec. The movements of T=1.0 sec. and the quick vibrations of T=¼ sec. (approx.) existed in both components.

The "initial vibration" was entirely in the longitudinal component, i.e., the inward and the outward displacements directly due to the explosion moved in the line joining the observing place with the crater centre. The large (absolute maximum) slow oscillation of 2a=0.122 mm, which occurred only 2.4 sec. after the "initial vibration," was also purely longitudinal, being mixed only with two small vibrations of 2a=0.009 mm in the transverse direction.

35. *Explosion of Oct. 7th, 1913, at 11. 32. 32 a.m.* * This was a comparatively small explosion. At Ashino-taira, the building was slightly shaken, followed by a rushing sound. At the Asama Pasture Ground, noises continued to be heard for about 25 sec. after the explosion.

Total Duration=2^m 10^s. The explosion was small.

Longitudinal Component. The motion was made up principally of slow vibrations of T=1.0 sec., max. 2a=0.0072 mm, mixed with those of T=0.61 sec., there being practically no superposition of quick movements.

Transverse Component. The vibrations were regular: T=1.05 sec., max. 2 a=0.0093 mm.

36. *Explosion of Oct. 15th, 1913, at 10. 43. 13 p.m.* ** At Ashino-taira, a detonation like that of a gun discharge was heard. At the Asama Pasture Ground the detonation was very loud.

Total Duration=2^m 20^s.

Transverse Component. (Fig. 47.) The preliminary portion was very small and lasted 0.62 sec. Then there took place a slow vibration of T=1.6 sec., whose 1st and 2nd displacements were 0.0063 and 0.0128 mm respectively. For the next 4.5 sec., there were 5 regular vibrations of T=0.89 sec., of which the 3rd one had the max. 2a of 0.0218 mm. For the next 3.4 sec., the motion was slightly smaller and irregular: T=0.48 sec., max. 2a 0.0088 mm. So far, for the 1st 10.1 sec., the movements were comparatively small. During the next 9.5 sec., the motion was most active and composed of 9 large well defined vibrations of T=1.05 sec., the last but one of which had the absolutely greatest 2a of 0.068 mm. It was just immediately after the commencement of this maximum movement, that the effect of the sound shock (Fig. 47) was indicated in a perfectly definite manner. Thus the detonation arrived at the Asama Pasture Ground 17.5 sec. later than the commencement of the earthquake motion. For the next 13.7 sec., the motion was much smaller and composed principally of the vibrations of T=0.93 sec., max. 2a=0.0244 mm; there being during the 1st 3.3 sec. a superposition of the quick movements caused by the detonation. For the next 12.4 sec., the motion again decreased, and consisted of 15 regular vibrations of T=0.83 sec., max. 2a=0.0091 mm. The subsequent motion was very small.

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* Time at Ashino-taira.

** Time at Ashino-taira.

Longitudinal Component. The record is unfortunately imperfect, as, at the time of the explosion, the writing stile remained suspended up and was not recording on the smoked paper, being first caused to drop down on the latter by the sound shock. The quick movements due to the latter appeared then for about 5.6 sec: T=0.22 sec., max. 2 a=0.0315 mm. The period of the slower vibrations, which occurred throughout the rest of the motion, was 1.02 sec.

37. ***Explosion of Oct. 17th, 1913, at 3. 27. 47 p.m.*** At Ashino-taira, the detonation was feeble and much less intense than that on the 15th; the amplitude of the earthquake vibration being, however, greater on the present occasion. At the Asama Pasture Ground, the detonation was very loud and of a long duration, and was followed for some time by rushing noises. The smokes were carried by S. winds past over the last named place, where, however, there was no precipitation of ashes.

Total Duration$=1^m\ 50^s$.

Longitudinal Component. [Preliminary and principal portions: duration=36 sec.] The earthquake began with an inward displacement of 0.0062 mm and of duration=1.27 sec., the preliminary outward motion being small and consequently not separately indicated. The 2nd and outward displacement was 0.0206 mm (duration=1.26 sec.), forming together with the preceding the "initial vibration" of T=2.54 sec. Again, the 2nd displacement and the next small vibration may be regarded as together forming a slow movement of 2a=0.0312 mm and of duration=1.76 sec. There followed two nearly equal well defined displacements forming a vibration of T=2.4 sec., 2a=0.087 mm. Then took place a slow inward displacement of 0.062 mm (duration=2.1 sec.), mixed with smaller movements. For the next 5.3 sec., there were two slow vibrations of T=2.65 sec., the 1st of which had the absolutely maximum 2a of 0.112 mm, and which were mixed amongst the others with quick movements of T=0.36 sec.; these latter becoming prominent from about 10.3 sec. after the earthquake commencement. During the next 10.6 sec., there were 15 well defined regular vibrations of T=0.71 sec., of which the 1st had the 2a of 0.0644 mm, and the 6th the max. 2a of 0.0717 mm, on account of the superposition of the effect of the detonation wave; this latter having appeared 17.2 sec. after the earthquake commencement, or 16.0 sec. after the end of the 1st displacement of the "initial vibration." During the remaining 11.3 sec., the motion was less, being composed of $14\frac{1}{2}$ vibrations of T=0.78 sec., 2a=0.0312 mm, mixed with some quick movements. [End portion.] Motion was very much smaller.

Transverse Component. [Preliminary and principal portions: duration=27.3 sec.] The motion, whose commencement was clearly marked, was very small during the 1st 1.36 sec. Then took place a movement of 0.0079 mm (duration=0.64 sec.), toward NNW, followed by a vibration of T=2.53 sec. composed of the two displacements respectively of 0.0352 and 0.0692 mm. The next 4.4 sec. was made up of a single slow vibration mixed with smaller ones of T=0.50 sec. (2a=0.013 mm); the superposed quick movements beginning to appear at the end of this interval, namely, from about 8.8 sec. after the earthquake commencement. Then took place a large vibration of T=2.48 sec., and of 2a=0.106 mm, mixed with smaller ones. For the remaining 18.4 sec., the motion was most active and was composed of well defined vibrations of T=1.03 sec., max. 2a=0.0715 mm, and of T=0.79 sec., max. 2a=0.0664 mm. [End portion.] During the 1st 14.1 sec., the motion was small: T=1.1 sec., 2a=0.012 mm, and of T=0.7 sec., max. 2a=0.0173 mm. The subsequent motion was very small. [Sound Shock.] The effect due to the sound shock occurred 17.0 sec. after the earthquake commencement.

Comparison of Longitudinal and Transverse Components. The 1st or inward displacement of the "initial vibration" (resultant 2a=0.0062 mm) was entirely longitudinal, while the 2nd, or outward, displacement (resultant 2a=0.021 mm) deviated about 22° from the radial direction. The slow period large (absolute maximum) displacement of 0.106 mm in the transverse component took place 1.05 sec. later than the corresponding displacement of 0.112 mm in the longitudinal. In the subsequent portion, there was no great difference in the amplitude of motion between the two components.

38. *Explosion of Oct. 22nd, 1913, at 3. 55. 42 a.m.* A small explosion, which caused the precipitation of sands at the Asama Pasture Ground for about 10 minutes.

Total duration$=2^m\ 0^s$. The commencement was slightly indistinct.

Longitudinal Component. [Preliminary and principal portions: duration=26.9 sec.] The diagram is, on the whole, similar almost vibration for vibration to that of the explosion on Oct. 17th. In the present case, however, the motion was much smaller, and began with the preliminary portion of 1.6 sec. duration, followed by an inward displacement of 0.0018 mm (duration=1.44 sec.), and the outward one of 0.0099 mm (duration=1.69 sec.); the two forming a slow vibration of T=3.1 sec., corresponding to the "initial vibration." The next vibration, of T=2.2 sec., was composed of the two displacements respectively of 0.0176 and 0.0422 mm; quick superposed movements of 2a=0.0154 mm appearing from about 4.4 sec. after the earthquake commencement. For the remaining 20.0 sec., the motion was active and consisted of the well defined vibrations of T=0.80 sec., of which the 2nd had the absolutely maximum 2a of 0.073 mm; the max. 2a of the superposed quick movements (T=0.27 sec.) being 0.0277 mm. [End portion.] The motion was small, being composed of the vibrations of T=1.4 sec. (2a=0.0107 mm), T=0.74 sec. (2a=0.012 mm), etc. The sound effect was indicated somewhat doubtfully 16.5 sec. after the end of the 1st displacement of the "initial vibration."

Transverse Component. [Preliminary and principal portions:

duration=24.5 sec.] The motion was practically *nil* during the 1st 2.5 sec. Then took place a vibration of T=2.0 sec., composed of the two displacements of 0.0036 and 0.010 mm respectively toward NNW and SSE. For the next 6.6 sec., there were 2½ slow vibrations of T=2.6 sec., of which the 2nd had the max. 2a of 0.078 mm; there being superpositions of quicker movements of T=0.81 sec. (2a=0.035 mm), and some smaller ones. For the next 13.4 sec., the motion consisted of 14½ regular vibrations of T=0.92 sec., of which the 2nd had the max. 2a of 0.049 mm. The subsequent motion was much smaller: T=1.1 sec., 2a=0.015 mm.

Comparison of Longitudinal and Transverse Components. The 1st, or inward, displacement of the "initial vibration" was entirely longitudinal. The absolute maximum 2a of 0.078 mm in the transverse component occurred 8.6 sec. after the earthquake commencement, or about 0.7 sec. after the corresponding motion of 0.073 mm in the other. The regular vibrations in the transverse component between 11.2 and 23.5 sec. after the commencement were on the whole distinctly larger than the movements in the corresponding interval in the longitudinal; although the quick superposed movements, which were markedly shown in the latter, were practically *nil* in the former component.

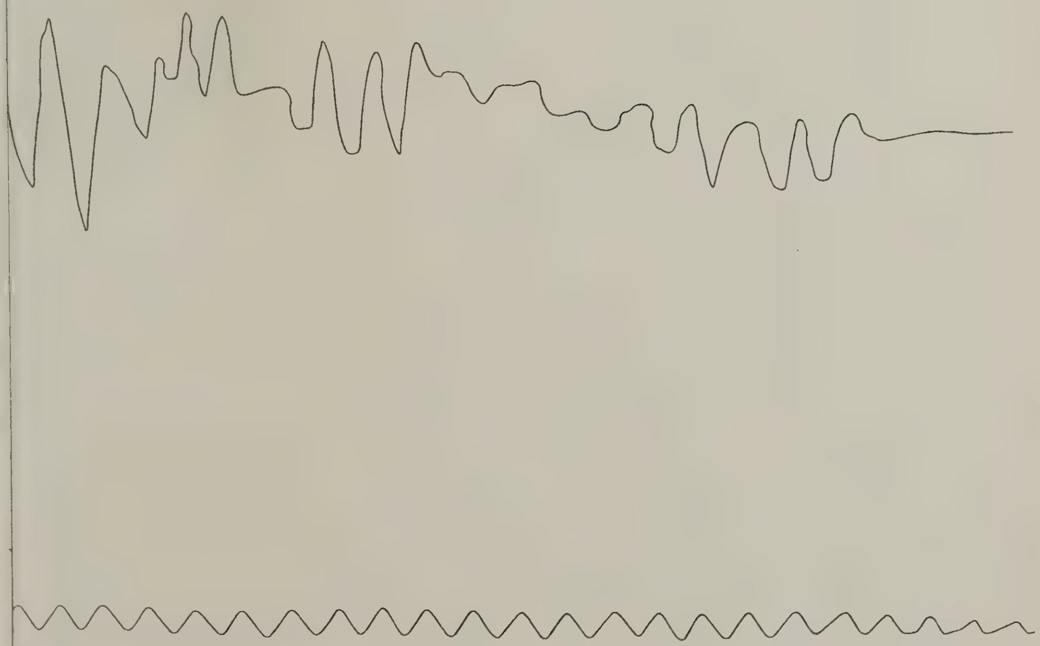
39. *Explosion of Nov. 14th, 1913, at 11. 11. 55 a.m.* At the Asama Pasture Ground, the detonation was very loud and like a thunder peal, followed by rushing noises for about 3 minutes. (See Fig. 9.)

Total Duration=3 min. (Fig. 49.)

Longitudinal Component. [Preliminary and principal portions: duration=22.3 sec.] The motion was very slight during the 1st 1.9 sec., after which a small outward displacement of 0.0057 mm

Pl. XVII.

e Ground.

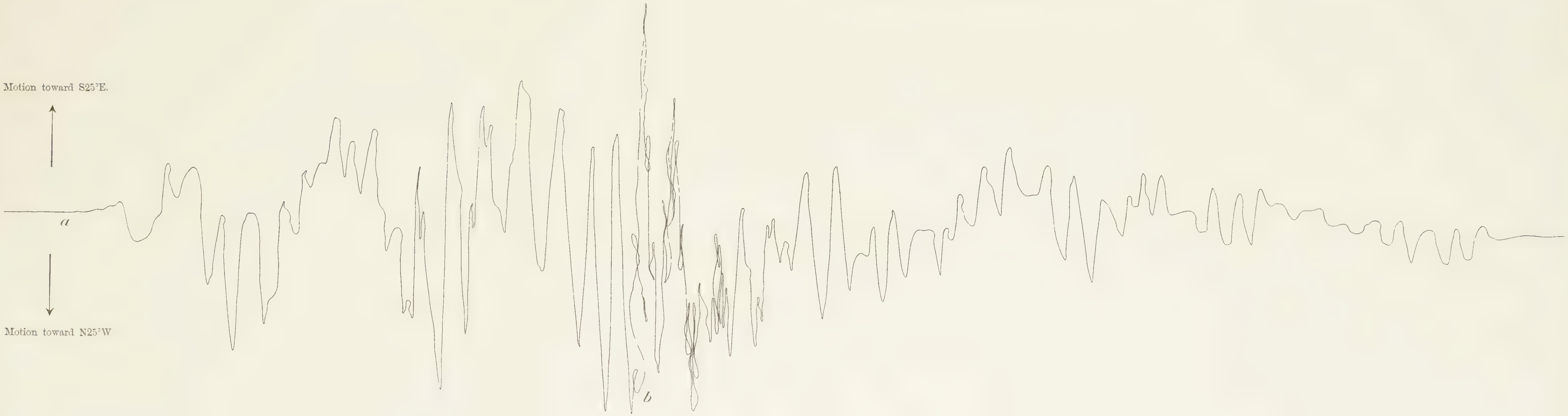


tion = 1130
le : 1 Minute = 282 mm.

Fig. 47. Asama-yama Explosion of Oct. 15th, 1913, observed at Asama Pasture Ground.

Transverse Component.

Magnification = 1610.
Time Scale: 1 Minute = 483 mm.
a....Commencement. b....Sound Shock.



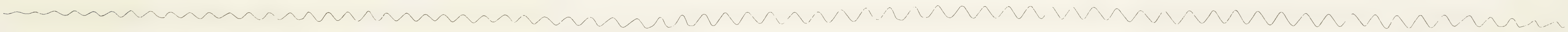
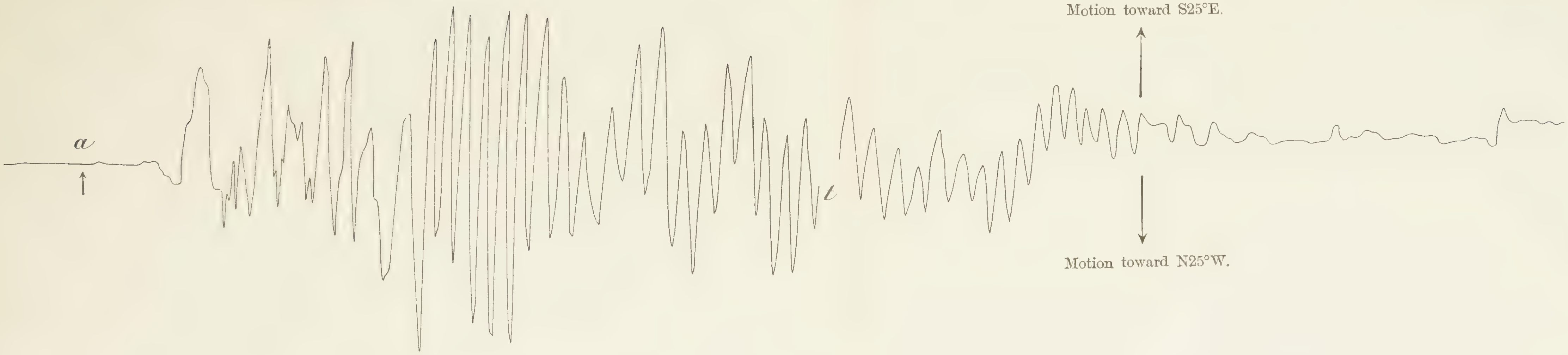


Fig. 48. Micro-Pulsations, observed on Aug. 12th, 1913, at about 1½ p.m.
Yuno-taira Tromometer Record: Longitudinal Component.

Magnification = 1130
Time Scale: 1 Minute = 282 mm.

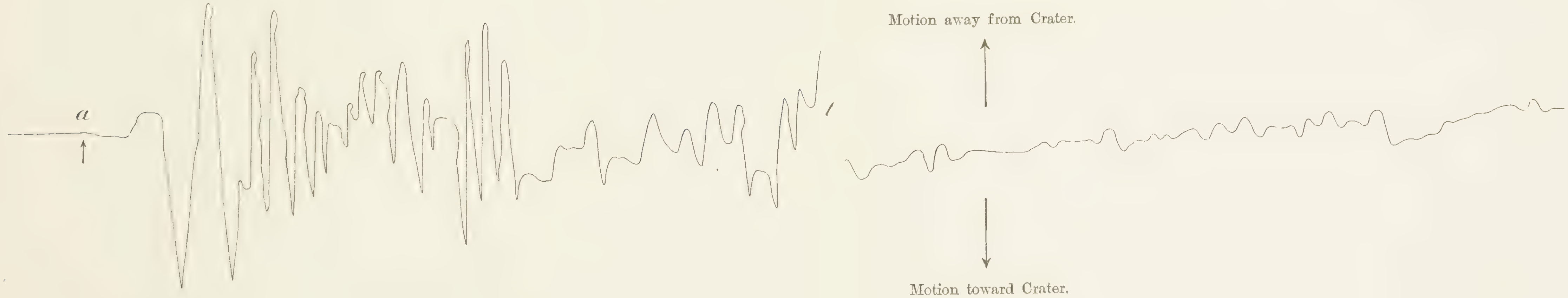
Fig. 49. Asama-yama Explosion of Nov. 14th, 1913, observed at Asama Pasture Ground. Tremor-recorder Diagram.

Transverse Component.



Magnification = 790. t....Minute Cutting.
Time Scale: 1 minute = 51 mm. a....Commencement.

Longitudinal Component.



Pl. XIX.

Nov. 20th, 1913,

two components.

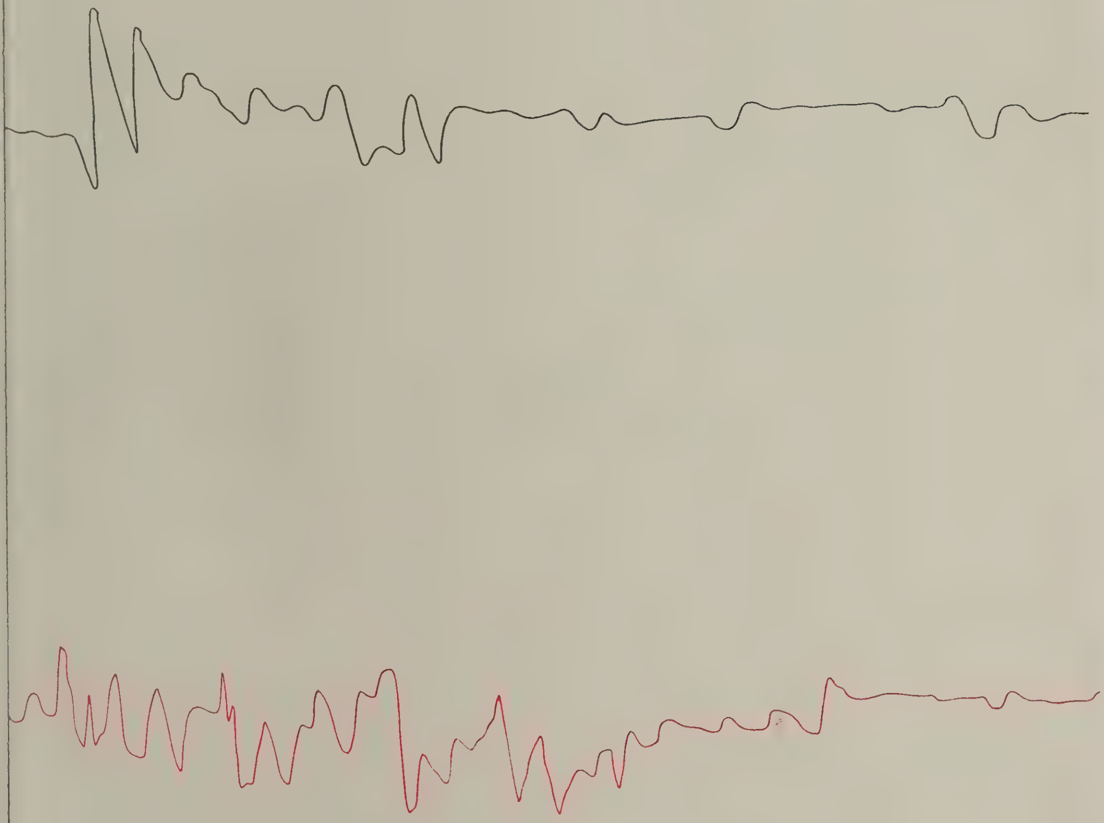
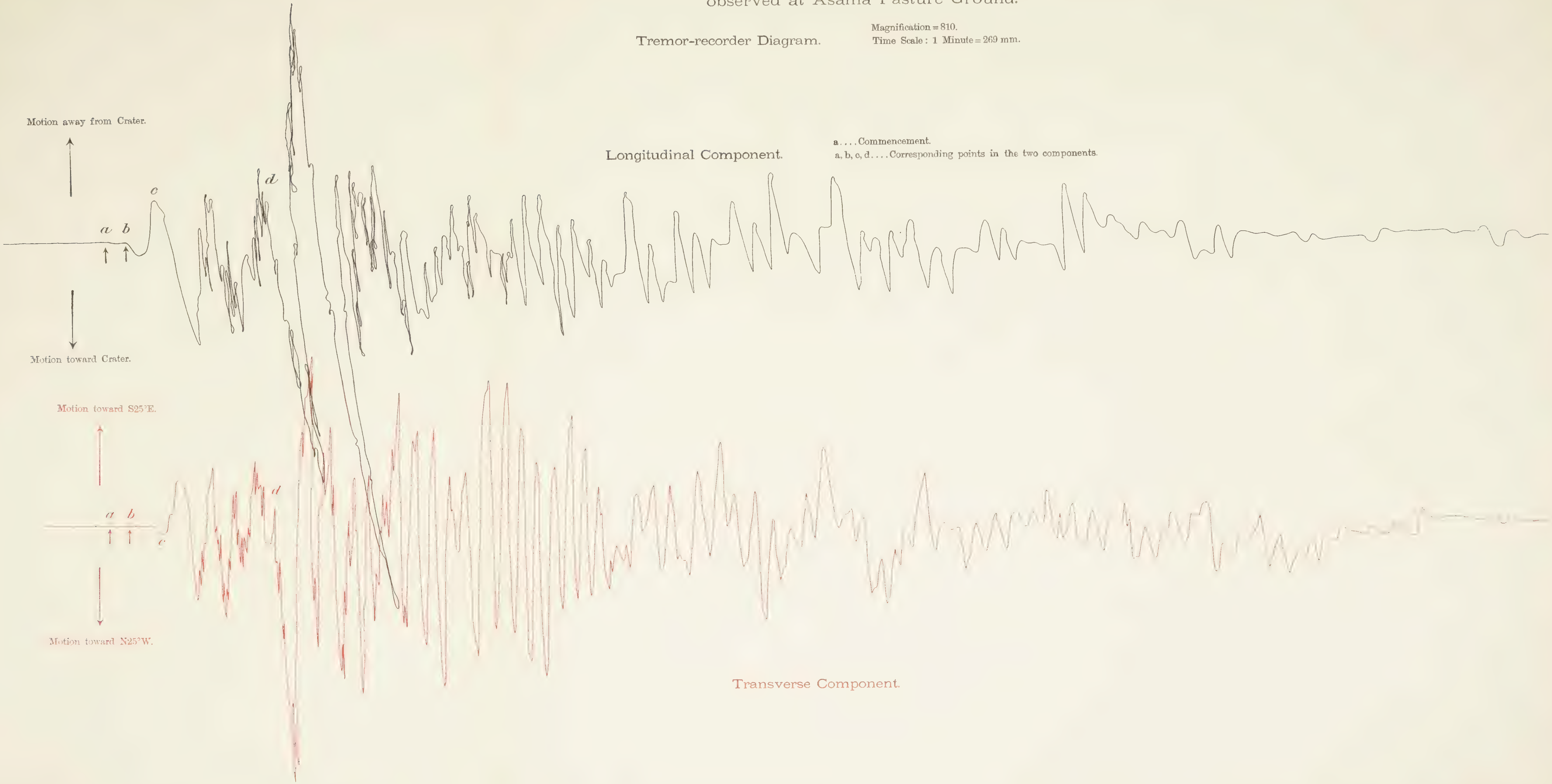


Fig. 50. Non-Detonative Eruption of Asama-yama of Nov. 20th, 1913, observed at Asama Pasture Ground.

Tremor-recorder Diagram.

Magnification = 810.
Time Scale: 1 Minute = 269 mm.



(duration=1.2 sec.) took place. Then there followed the "initial vibration" of T=3.05 sec., composed of the inward displacement of 0.038 mm and of the outward one of 0.063 mm. The latter and the 3rd motion of 0.059 mm together formed a large vibration of T=2.7 sec. For the remaining 14.6 sec., the motion became quick and was composed of 15 well defined vibrations of T=0.97 sec., max. 2a=0.046 mm. [End portion.] During the 1st 17.3 sec., the vibrations were: T=1.47 sec., max. 2a=0.024 mm. Thereafter the motion became much smaller, being composed of the movements of T=1.3 sec., max. 2a=0.007 mm. Towards the very end, the period was 1.05 sec.

Transverse Component. [Preliminary and principal portions: duration=37.7 sec.] The motion was practically *nil* for the 1st 3.6 sec., after which took place a SSE'ward displacement of 0.0048 mm (duration=1.2 sec.) corresponding to the 1st, or inward, movement of the "initial vibration" in the longitudinal component. The two next displacements, respectively of 0.025 and 0.035 mm formed a slow vibration of T=2.57 sec. For the next 10.1 sec., there were 7 slow vibrations of T=1.44 sec., (with some superposition of small quick movements), the last having the max. 2a of 0.052 mm. Then there took place a slight quickening of period, and, for the next 7.8 sec., the motion was most active, being composed of 8 regular vibrations of T=0.98 sec., max. 2a=0.073 mm. For the remaining 12.8 sec. of the principal portion, the motion was nearly uniform: T=1.16 sec., max. 2a=0.048 mm. [End portion.] During the 1st 17.4 sec., the vibrations were regular: T=1.03 sec., max. 2a=0.017 mm. Thereafter the motion became much smaller.

Comparison of Longitudinal and Transverse Components. The introductory small motion phase lasted in the transverse component

(duration=1.2 sec.) took place. Then there followed the "initial vibration" of T=3.05 sec., composed of the inward displacement of 0.038 mm and of the outward one of 0.063 mm. The latter and the 3rd motion of 0.059 mm together formed a large vibration of T=2.7 sec. For the remaining 14.6 sec., the motion became quick and was composed of 15 well defined vibrations of T=0.97 sec., max. 2a=0.046 mm. [End portion.] During the 1st 17.3 sec., the vibrations were: T=1.47 sec., max. 2a=0.024 mm. Thereafter the motion became much smaller, being composed of the movements of T=1.3 sec., max. 2a=0.007 mm. Towards the very end, the period was 1.05 sec.

Transverse Component. [Preliminary and principal portions: duration=37.7 sec.] The motion was practically *nil* for the 1st 3.6 sec., after which took place a SSE'ward displacement of 0.0048 mm (duration=1.2 sec.) corresponding to the 1st, or inward, movement of the "initial vibration" in the longitudinal component. The two next displacements, respectively of 0.025 and 0.035 mm formed a slow vibration of T=2.57 sec. For the next 10.1 sec., there were 7 slow vibrations of T=1.44 sec., (with some superposition of small quick movements), the last having the max. 2a of 0.052 mm. Then there took place a slight quickening of period, and, for the next 7.8 sec., the motion was most active, being composed of 8 regular vibrations of T=0.98 sec., max. 2a=0.073 mm. For the remaining 12.8 sec. of the principal portion, the motion was nearly uniform: T=1.16 sec., max. 2a=0.048 mm. [End portion.] During the 1st 17.4 sec., the vibrations were regular: T=1.03 sec., max. 2a=0.017 mm. Thereafter the motion became much smaller.

Comparison of Longitudinal and Transverse Components. The introductory small motion phase lasted in the transverse component

3.6 sec., or 1.7 sec. longer than in the longitudinal. The two displacements composing the "initial vibration" were much greater in the latter than in the former, the resultants being 0.038 mm toward S55° W and 0.068 mm toward N40°E. Thus, in the present case, the directions of the "inward" and the "outward" movements deviated leftwards from the line joining the observing place with the crater centre respectively by the amounts of 7° and 22°. In the transverse component, large (absolute maximum) regular vibrations set in 17.2 sec. after the earthquake commencement, while in the longitudinal component there was in the same epoch no marked corresponding amplification of the vibrations.

CHAPTER V. STRONG ASAMA-YAMA EXPLOSIONS OBSERVED AT ASHINO-TAIRA.*

[TREMOR-RECORDER DIAGRAMS.]

40. *Explosion of Sept. 21st, 1913, at 1. 50. 59 p.m.* Total duration=97 sec.

Longitudinal Component. [Preliminary and principal portions: duration=24.8 sec.] The preliminary motion of 0.0025 mm (duration=0.49 sec.) was followed by the "initial vibration" of T=2.2 sec., composed of the 1st or inward displacement of 0.030 mm (duration=0.97 sec.), and of the 2nd or outward displacement of 0.077 mm (duration=1.22 sec.). The latter was followed by the inward and maximum 2a of 0.093 mm, the two together forming a well defind vibration of T=2.43 sec. Then followed a slow outward displacement (duration=2.1 sec.) of 0.057 mm. So far, for the first 6.1 sec. the motion was gentle, there being practically no superposition of the quick movements.

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* The times of occurrence of the explosions considered in this chapter are those registered by a tremor-recorder at Ashino-taira.

For the next 14.5 sec., the motion was composed of the vibrations of T=1.04 sec., and max. 2a=0.034 mm, mixed with quick movements of T=0.36 sec., and of max. 2a=0.020 mm. During this interval, there appeared 4 pendulum oscillations of period of 3.6 sec., and of maximum range of about 0.017 mm. The subsequent motion was smaller. [Sound Shock.] The maximum quick vibrations, which occurred 14.0 sec. from the earthquake commencement, or 12.5 sec. after the end of the 1st displacement of the "initial vibration," may possibly denote the effect of the sound shock. [End portion.] The motion consisted of regular vibrations of T=1.45 sec., 2a=0.0048 mm, mixed with traces of small quick movements.

Transverse Component. [Preliminary and principal portions: duration=23.3 sec.] The motion was very small for the 1st 1.8 sec., after which a left-hand side displacement of 0.0048 mm (duration=0.66 sec.) took place, followed by the counter motion of 0.015 mm (duration=0.66 sec.). For the next 4.3 sec. there were 1½ slow oscillations of T=2.9 sec., of which the max. 2a of 0.064 mm occurred 6.2 sec. after the commencement, these being mixed with smaller movements of T=1.2 sec. During the rest of the principal portion, the motion was much smaller and consisted of the vibrations of T=0.87 sec., 2a=0.014 mm, mixed with some slower movements. [End portion.] Max. 2a=0.0044 mm. The effect of the detonation was not indicated.

41. *Explosion of Oct. 9th, 1913, at 1.09.10 a.m.* Total duration=70 sec.

Longitudinal Component. The preliminary outward motion, was very small (0.0011 mm) and lasted 0.52 sec. The "initial vibration," of T=2.3 sec., was composed of the 1st and 2nd displacements respectively of 0.0045 mm (duration=1.06 sec.) and

0.0175 mm (duration=1.21 sec.). Then there followed another slow vibration of T=2.6 sec., composed of the 1st and 2nd displacements respectively of 0.021 mm (duration=1.5 sec.) and 0.011 mm (duration=1.1 sec.). So far, for the 1st 5.6 sec., the motion was slow and free from superpositions of smaller movements. Then there appeared quick vibrations of T=0.31 sec., which were small for the 1st 0.96 sec. (2a=0.002 mm), then became larger (2a=0.0076 mm), and reached the max. 2a of 0.0175 mm after 0.9 sec., or 7.4 sec. from the earthquake commencement. For 15.3 from the moment of appearance of these quick movements, there were mixtures of slow vibrations of T=1.4 sec. (2a=0.011 mm), and other ones. During the rest of the earthquake, the motion consisted of regular vibrations of T=1.2 sec., 2a=0.0018 mm, mixed with traces of quick movements.

Transverse Component. During the 1st 14.1 sec. the motion consisted of slow vibrations of T=1.6 sec. (2a=0.008 mm) mixed with some smaller ones. During the next 12.9 sec., small vibrations of T=0.38 sec. were mixed with the slower ones of T=0.9 sec. (2a=0.0028 mm). Thereafter the movements became regular: T=1.12 sec., 2a=0.0011 mm.

42. *Explosion of Oct. 15th, 1913, at 10. 43. 13 p.m.* Total duration=1^m 34^s.

Longitudinal Component. The very small preliminary outward motion of 0.0015 mm (duration=0.5 sec.) was followed by the "initial vibration" of T=2.2 sec., composed of the 1st and 2nd displacements respectively of 0.009 mm (duration=1.05 sec.) and of 0.035 mm (duration=1.15 sec.). The effect due to the sound shock, which arrived 14.4 sec. after the commencement of the motion, or 12.8 sec. after the stage corresponding to the moment of the explosion, was markedly larger than the proper earthquake vibrations, being active (2a=0.065 mm) for 1.15 sec., and lasting for further 1.15 sec. The subsequent motion was small.

Transverse Component. The principal vibration periods was T=1.01 sec. (max. 2a=0.0206 mm). The sound effect (max. 2a=0.0225 mm), which occurred 14.3 sec. after the commencement, lasted 1.7 sec.

43. ***Explosion of Oct. 17th, 1913, at 3. 27. 47 p.m.*** Total duration=$1^m\ 56^s$.

Longitudinal Component. [Preliminary and principal portions: duration=21.8 sec.] The earthquake began with an inward displacement of 0.0076 mm (duration=1.5 sec.), followed by the counter motion of 0.0383 mm (duration=1.2 sec.). For the next 12.8 sec. there were 4 large slow vibrations of T=3.2 sec., max. 2a=0.0663 mm, with superposition of some quicker movements. During the rest of the principal portion, the motion decreased. [End portion]. The motion was composed of the vibrations of T=1.47 sec. (2a=0.0024 mm), mixed with those of T=1.05 sec., and others.

Both *before* and *after* the earthquake, there were small vibrations of T=3.6 sec., max. 2a=0.0012 mm.

Transverse Component. [Preliminary and principal portions: duration=16.6 sec.] The preliminary displacement was very small and lasted 1.2 sec., after which took a SSE'ward displacement of 0.0018 mm (duration=0.5 sec.). During the whole remainder of the principal portion, the motion was made up of the vibrations of T=1.35 sec., of which the maximum one of 0.038 mm occurred 10.1 sec. after the commencement of the earthquake; these being grouped into slow oscillations of T=3.8 sec. [End portion.] The vibrations of T=1.3 sec. (2 a=0.0053 mm) were mixed with others. The period of the *pulsatory oscillations* before and after the earthquake was about 3.8 sec.

44. *Explosion of Oct. 22nd, 1913, at 3. 55. 42 a.m.* Total duration=1^m 44^s.

Longitudinal Component. [Preliminary and principal portions: duration=17.2 sec.] The preliminary motion lasted 1.0 sec. and was practically *nil.* Then took place the "initial vibration" of T=2.2 sec., composed of the 1st and 2nd displacements respectively of 0.0012 mm (duration=0.9 sec.) and 0.0069 mm (duration =1.3 sec.). For the next 11.4 sec., there were 6 vibrations of T=1.9 sec., of which the 3rd had the greatest 2a of 0.0275 mm, and which were grouped into those of double period; the quick superposed movements appearing from about 4.4 sec. after the commencement till the end of the epoch here considered. For the next 9.7 sec., the motion was composed of the quickly decreasing vibrations of T=0.88 sec., the 1st of which had the max. 2a of 0.0218 mm. The subsequent portion of the earthquake motion was composed of the vibrations of T=2.1 sec. (2a=0.0042 mm), mixed with those of T=0.98 sec.

Transverse Component. [Preliminary and principal portions: duration=19.4 sec.] The motion was very small during the 1st 1.9 sec. During the next 8.3 sec. there were 3 gradually increasing vibrations of T=2.8 sec., and of max. 2a=0.0206 mm, there being superpositions of quicker movements. During the rest of the principal portion the vibrations were smaller: T=0.73 sec., T=1.4 sec. In the end portion, the vibrations of T=1.9 sec. (max 2a=0.0012 mm), were mixed with quicker ones.

CHAPTER VI. STRONG ASAMA-YAMA EXPLOSIONS OBSERVED AT YUNO-TAIRA.*

45. ***Explosion of May 16th, 1913, at 4. 41. 00 p.m.*** According to Mr. Kurosaka, this strong explosion was felt at the Yuno-taira observatory as a loud detonation like that of a gun discharge, which shook the building for 1 or 2 sec., being followed for about 8 min. by rushing sounds like that of a violent gush of wind, although it had then been almost perfectly calm. The thick snow fall at the time of the eruption prevented the condition of the mountain being ascertained. Mr. Kurosaka ascended to the mountain top on the 19th and found the Muken-dani and the slope of the central cone covered by light masses of yellow-brownish lava fragments, while there were several new solid rock pieces, 1 foot or so in diameter, which were projected as far as the lower part of the Yuno-taira plateau, charring the grasses on which they fell.

Tromometer Diagram : *Longitudinal Component.* Total duration =95 sec. [Preliminary and principal portions : duration=28.5 sec.] The preliminary displacement was 0.0051 mm (duration=0.26 sec.) away from the mountain. Then followed a large displacement of 0.070 mm toward the origin, and the counter motion of 0.102 mm away from the latter, these two forming the " initial," and at the same time, maximum vibration of T=1.52 sec. For the next 14.7 sec., the motion remained active (max. 2 a=0.059 mm), and consisted of the vibrations of T=1.47 sec. mixed with those of T=0.61 sec., and others still quicker. During the remaining 10.5 sec. of the principal portion the motion became small.

46. ***Explosion of May 27th, 1913, at 5. 22. 57 a.m.*** At the

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* The times of occurrence of the explosions considered in this chapter are those registered by the tromometers at the Yuno-taira observatory.

Yuno-taira observatory, a loud detonation was heard at about 5. 23. 04 a.m., while the time of the earthquake occurrence indicated in the tromometer diagrams was 5. 22. 57 a.m. As it was then heavily raining and deeply misty, the condition of the mountain could not be ascertained. At Naganohara, a violent detonation like a gun discharge shook the houses strongly, causing damage to earthenwares which were thrown down from shelves. At Kusatsu, the sound was loud and produced much horizontal shakings of the houses. The sound was also heard at Komoro and Karuizawa.

(i) *Tromometer Diagram: Longitudinal Component.* Total duration=73 sec. [Preliminary and principal portions: duration=29.4 sec.] The 1st displacement, which was perfectly sudden, was 0.045 mm toward the monntain top, followed by the counter displacement of 0.062 mm, directed away from the latter; these two making up the slow and maximum "initial vibration" of T=1.3 sec. For the next 1.45 sec., the motion was small, being composed of 4 vibrations of T=0.36 sec., max. 2a=0.0096 mm, mixed with a slow motion. These were followed by three vibrations of T=1.3 sec., the 1st of which had the max. 2a of 0.039 mm; there being mixture of small movements of T=0.4 sec. Then, 6.0 sec. from the end of the 1st displacement of the "initial vibration," there began quick vibrations of T=0.44 sec., max. 2a=0.037 mm, which were probably due to the effect of the sound shock, and which remained active for 7.1 sec. During the remaining 15.6 sec. of the principal portion, the motion was smaller: 2a=0.0126 mm.

(ii) *Tremor-recorder Diagram: Transverse Component.* The principal portion lasted 21 sec. and consisted, during the first 6.7 sec., of regular vibrations of T=1.44 sec., max. 2a=0.054 mm.

Thereafter set in the mixture of quick movements which were due to the sound shock.

47. *Explosion of May 29th*, 1913, *at* 10. 44. 12 *a.m.* The eruption consisted of a strong explosion, not much inferior in intensity to those on May 8th and Oct. 22nd, 1911, and threw out a considerable amount of rock fragments around the crater to a radial distance of about 2 km; large hot pieces more than 1½ ft. in dimension, which fell at the foot of the Maikake-yama, charring the grasses and trees struck under them. In several cases the rock fragments of the size of a fist, which fell in the upper part of the Yuno-taira plateau, produced patches of burnt area to a maximum extension of about 7 metres diameter. According to Mr. Kurosaka, the detonation was at Yuno-taira very loud and suddenly shook the building, which continued to make slight movements for about 20 sec. Simultaneously a column of black smokes rose from above the thin layer of mists shrouding the mountain, accompanied by rushing sounds. The mists cleared off after one minute or so, when smoke column was observed continuing its ascent, while the rock fragments, which had fallen on the mid-slope of the Maikake-yama were in four or five points issuing white steams for 30 to 60 minutes. The sounds ceased after 5 min., all being restored to the normal state in 10 min.

This eruption was the third among the numerous outbursts since 1909, which was attended by fatal accident. Two young men, of the town of Murota, Gumma prefecture, who ascended the mountain on the same morning from Karuizawa, met the explosion and were struck by the stone fragments projected from the crater when they reached the Kenga-mine, the remnant of the old crater wall on the E. side, or the continuation of the Maikake-yama. One of them was severely wounded yet able to run down to the Wakasare Cottoge, while, the other was killed on the spot in consequence of the blows received on leg and neck. There were at the time of the eruption also a party of seven gardeners, who were collecting dwarf plants at the Tengu-no-roji. No sooner had they been startled by the loud detonation, than there fell ashes and hot rock fragments as large as fist. They ran for life towards the observatory and were able to reach a place outside the limit of the stone precipitation.

Tromometer Diagram: *Longitudinal Component.* Total duration =90 sec. [Preliminary and principal portions: duration=36.3 sec.] The earthquake began with a very small preliminary motion of 0.0023 mm (duration=0.16 sec.) directed away from the mountain. Then followed two large displacements of 0.048 and 0.098 mm, directed respectively toward and away from the origin, together making up the slow and maximum "initial vibration" of T=2.65 sec., mixed with those of T=0.44 sec. (max. 2a=0.028 mm). For the next 20.0 sec., the motion gradually decreased, consisting of slow vibrations of T of about 1.6 sec. (max. 2a=0.011 mm), mixed with quick movements of T=0.34 sec. (max. 2a=0.008 mm). The occasional groups of quick vibrations which occurred during this last phase of motion, at 24.2; 26.0; 27.8; 29.0; 31.0 sec. from the commencement of the earthquake, may possibly denote a series of small eruptions which followed the principal one. The sound shock occurred 7.0 sec. from the commencement, or 5.9 sec. after the end of the 1st displacement of the initial vibration. In Fig. 52 is also reproduced the vertical motion diagram, in which the vibrations were very small.

48. ***Explosion of June 13th, 1913, at 11. 01. 16 p.m.*** At Yuno-taira, there were perceived first rushing sounds, followed after a short time interval by a loud detonation like a gun discharge, the shakings of the building continuing for a few seconds. The smokes issuing from the crater threw out bright glowing lava pieces, and continued red like a distant conflagration for about 30 minutes.

Tromometer Diagram: *Longitudinal Component.* Total duration=72 sec. [Preliminary and principal portions: duration=23.2 sec.] This was a comparatively small disturbance, whose "initial vibration" was not definitely indicated. The motion was active during the 1st 13.4 sec., in which the principal period was 0.56 sec. (?), with mixture of other periods, the max. 2a of 0.020 mm having taken place 8.0 sec. after the commencement. During the remaining 9.8 sec., of the principal portion, the motion was smaller: 2a=0.0057 mm., T=0.4 sec.

49. *Explosion of June 17th*, 1913, *at* 10. 47. 41 *p.m.* This eruption of the Asama-yama, which had been quiet during the day time of the 17th, was very strong; at Yuno-taira, the detonation being excessively loud and shaking the observatory building violently. The whole slope of the Maikake-yama was instantly covered by red hot lava fragments, while the volcanic sounds and the noises caused by the falling projectiles were almost deafening. The effects of the light scintillation caused by the air currents and the hot materials were striking, such that the observer, Mr. J. Nishizawa, believed a torrent of lava and a "volcanic avalanch" were actually descending down the Maikake-yama toward the observatory, appearing to give no chance of escape to the inmates of the latter. The luminous lava pieces projected with considerable force from the crater, which looked like groups of shooting stars, passed overhead to places beyond the observatory, on whose roof were showered small lava fragments like hails. Some of the rock blocks which fell in the vicinity of the observatory and were partially buried in earth were found to glow red for over 15 minutes. Holes, about 3 metres in diameter, were formed at Yuno-taira. (See also § 6.)

(i) Unfortunately the tromometer, which was not in a good working order, registered only the commencement of the disturbance. It began with a small but distinct outward motion of 0.004 mm, followed by the "initial vibration" composed of the inward and the outward displacements respectively of about 0.051 and 0.11 mm, the latter being mixed with quick movements.

(ii) Tremor-Recorder Diagram. Total duration=120 sec.

Longitudinal Component. [Preliminary and principal portions: duration=34.2 sec.] The preliminary outward motion was 0.004 mm (duration=0.37 sec.). The two displacements of the "initial vibration" of T=2.8 sec. were respectively 0.053 mm (duration =1.0 sec.) and 0.11 mm (duration=1.8 sec.). The disturbances (greatest 2a=0.11 mm) due to the sound shock began to occur about 7.6 sec. after the earthquake commencement, or 6.2 sec. after the end of the 1st displacement of the "initial vibration"; the superposition of quick movements becoming thereafter very pronounced. The appearance of a new maximum group of these latter 23.7 sec. after the earthquake commencement was probably due to the effect of large lava blocks falling in the vicinity of the observatory.

Transverse Component. [Principal portion: duration=38.6 sec.] During the 1st 7.8 sec., the motion was comparatively small and simple: T=1.52 sec., max. 2a=0.063 mm. The interval between the moments of appearance of the effects due to the sound-shock and of the impact of the falling lava blocks was 16.1 sec., result in a perfect accordance with the longitudinal component register. The greatest 2a was 0.093 mm. [End portion.] At first there were vibrations of T=1.45 sec., 2a=0.004 mm.

50. ***Explosion of June 18th, 1913, at 6. 21. 03 a.m.*** At

Yuno-taira the building was shaken, a column of black smokes, unattended by a detonation, being ejected from the crater. At Naganohara a detonation was heard.

Tromometer Diagram: *Longitudinal Component.* Total duration=113 sec. [Preliminary and principal portions: duration=24.0 sec.] The earthquake began with a slow inward displacement (duration=3.5 sec.), which were mixed with small movements of T=0.78 sec., 2a=0.0014 mm and may be taken as comprising the preliminary tremor (about 1.5 sec. in duration) and the 1st displacement of the "initial vibration." The 2nd displacement of the latter was 0.0297 mm, and followed by a third slow motion of 0.0545 mm, these two being mixed with quick movements of T=0.39 sec., and together forming an oscillation of T=4.9 sec. For the next 8.2 sec., the motion was made up of quick regular vibrations of T=0.47 sec., the max. 2a of 0.0248 mm having taken place 11.8 sec. after the commencement of the earthquake. During the remaining 7.6 sec. of the principal portion, the motion was much smaller: principal T=0.84 sec., 2a=0.0046 mm. [End portion.] Principal T=1.0 sec., 2a=0.003 mm.

51. *Explosion of June 20th, 1913, at 4. 06. 47 a.m.* This was a comparatively small eruption. At Yuno-taira a detonation was heard, red hot lava fragments having been thrown out of the crater. According to the tremor-recorder diagram, the total duration was 94 sec., while the duration of the principal portion in the longitudinal and transverse components were respectively 11 and 7.8 sec. The two displacements of the "initial vibration," preceded by no preliminary portion, were 0.01 and 0.025 mm. In the transverse component, the movements in the principal portion were regular: T=1.18 sec., max. 2a= 0.02 mm.

52. *Explosion of June 24th, 1913, at 11. 37. 34 a.m.* The eruption consisted in a vertical ejection of black smokes, whose sound was, at Yuno-taira, like that of strong wind, the building being at the same time slightly shaken.

Tromometer Diagram: *Longitudinal Component.* Total duration =88 sec. [Preliminary and principal portions: duration=12.2 sec.] The preliminary motion was not shown, the earthquake beginning with the "initial vibration" of T=1.8 sec. composed of the 1st, or inward, displacement of 0.014 mm, and the 2nd, or outward, one of 0.0398 mm. The latter and the succeeding 4½ vibrations of T=0.37 sec., 2a=0.0174 mm, form together a slow oscillation of T=2.3 sec., 2a=0.048 mm. Then took place three slower vibrations (2a=0.015 mm) lasting together about 1.4 sec., when began the conspicuous quick movements of 2a=0.029 mm. Supposing these latter to be the effect of the sound shock, the interval between the arrivals of the latter and the end of the 1st displacement of the "initial vibration" comes out to be 4.1 sec. For the remaining 6.7 sec. of the principal portion, the motion was composed of the vibrations of T=0.36 sec., 2a=0.017 mm, mixed with those of T=1.1 sec., 2a=0.023 mm. [End portion.] During the 1st 19.3 sec., the motion was composed of the vibrations of of T=1.6 sec., max. 2a=0.0025 mm, mixed with the quicker ones of T=0.77 sec., max. 2a=0.0027 mm. Thereafter the motion was much smaller: T=1.2 sec.

53. *Explosion of June 26th, 1913, at 8. 09. 40 a.m.* At Yuno-taira the detonation was very loud, and the lava fragments which were thrown down on the slope of the Maikake-yama caused temporary conflagrations among the forests. Some of the fallen rock pieces continued to issue white smokes or vapours for about 30 minutes. At the base of the Asama-yama about 2 km to the NE of Komoro, the present author heard the detonation, composed of two sounds, which were only moderately loud and were separated by a time interval of about 0.5 sec. It is likely that the mountain slope forms a sort of shadow region, where the detonations are heard only with diminished intensity, or even not heard at all.

Tromometer Diagram: Longitudinal Component. Total duration=115 sec. [Preliminary and principal portions: duration=16.2 sec.] The very small preliminary motion of 0.0007 mm (duration=0.47 sec.) was followed by the "initial vibration" of T=1.74 sec., composed of the 1st, or inward, displacement of 0.021 mm, and the 2nd, or outward, one of 0.0403 mm. Then followed a smaller well defined vibration of T=1.36 sec., and 2a=0.021 mm (duration=0.86 sec.) and a slow (inward) motion of 2a=0.036 mm; these forming, together with the 2nd displacement of the "initial vibration," an oscillation of T=3.0 sec., 2a=0.045 mm. For the next 4.2 sec., the motion was nearly uniform, and composed of the vibrations of T=0.71 sec., max. 2a=0.0162 mm; the most conspicuous movement of 2a=0.0184 mm, which may denote the effect of the sound shock, occurring at the end of this interval, or 6.6 sec. after the end of the 1st displacement of the "initial vibration." During the remaining 7.5 sec. of the principal portion, the motion was smaller: T=0.63 sec., max. 2a=0.0134 mm. [End portion.] During the 1st 9.2 sec., the motion was comparatively large, and composed of the vibration of T=1.4 sec., max. 2a=0.0018 mm, mixed with small quicker ones of T=0.75 sec. Thereafter the motion was smaller.

54. *Explosion of June 26th*, 1913, *at* 11. 41. 59 *p.m.* The author, who was staying at the time in the observatory of Yunotaira, was aroused from sleep by the violent detonation, whose time moment noted from a watch near by was 8 sec. after the arrival of the earthquake motion indicated by the tromometer, and which may be likened to a loud thunder or artillery peal of some duration, causing sharp rattlings and shakings of the building. When he rushed out of doors, after having noted the time from the watch, the Maikake-yama, which was covered by thick mists, was enveloped in a pink light, while the lava fragments projected down there were glowing like huge stars or white gas lights at a distance. The smokes became obscure rather abruptly $1^m\ 40^s$ after the arrival of the detonation, although the rushing sounds were heard for 2 minutes longer.

Tromometer Diagram: *Longitudinal Component.* Total duration=150 sec. [Preliminary and principal portions: duration=28.9 sec.] The very small preliminary motion of 0.0008 mm (duration=0.37 sec.) was followed by the conspicuous "initial vibration," of T=2.3 sec., composed of the 1st, or inward, displacement of 0.064 mm, and the 2nd, or outward, one of 0.093 mm. The latter and the succeeding 5½ vibrations of T=0.89 sec., and max. 2a=0.041 mm, form together a slow oscillation of T=5.8 sec. and of 2a=0.140 mm. Then set in a slow pendulum motion (T=15.2 sec.) of the steady mass of the seismograph, the quick superposed vibrations, to be supposed to be the effect of the "sound shock," becoming at the same time very conspicuous and continuing active for 8.5 sec.: T=0.59 sec., max. 2a=0.083 mm. The time interval between the end of the 1st displacement of the "initial vibration" and the appearance of the sound shock was about 6.1 sec. During the remaining 13.2 sec. of the principal portion, the motion consisted of vibrations of T=0.75 sec., 2a=0.023 mm. [End portion.] The motion was composed of the vibrations of T=2.2 sec., 2a=0.0065 mm, mixed with the small movements of T=0.79 sec.

55. *Explosion of July 7th,* 1913, *at* 7. 10. 32 *a.m.* At Yunotaira, a detonation of short duration caused some shakings of the glass doors and of the building. The black smokes rose high up in a vertical column presenting a magnificent sight. The eruption force was, however, comparatively weak, there being apparently no precipitation of lava masses on the Maikake-yama.

Tromometer Diagram : Longitudinal Component. Total duration =78 sec. [Preliminary and principal portions: duration=12.4 sec.] The preliminary displacement was 0.0009 mm, directed outwards. The "initial vibration" of T=1.48 sec. was composed of the inward motion of 0.017 mm (duration=0.7 sec.) and the outward motion of 0.037 mm (duration=0.78 sec.). For the next 4.0 sec., there were 3 slow vibrations of T=1.33 sec., 2a=0.022 mm, mixed with smaller movements. For the remaining 6.7 sec. of the principal portion, the motion was composed of nearly equal vibrations of T=0.4 sec., 2 a=0.019 mm, more or less grouped into the traces of slower movements of T=1.34 sec. [End portion.] During the 1st 7.6 sec.: T=0.85 sec., max. 2a=0.009 mm. During the next 7.2 sec., the motion was smaller, T=0.72 sec., max. 2a =0.005 mm. The subsequent portion was very small.

56. *Explosion of July 7th,* 1913, *at* 9. 46. 53 *p.m.* At Yunotaira, a detonation caused shakings of the building. As the cloud layers were high, although it was raining at the time, the smokes were seen wholly ablaze. The glowing lava fragments fell only around the crater and did not reach to the slope of the Maikake-yama. For about 15 minutes, the mountain top presented a sight like a distant conflagration.

(i) *Tromometer Diagram: Longitudinal Component.* Total duration=126 sec. [Preliminary and principal portions: duration=15.1 sec.] The earthquake began with a preliminary motion of 0.0019 mm (duration=0.47 sec.) and the "initial vibration" of T=1.61 sec., composed of the 1st (inward) and 2nd (outward) displacements respectively of 0.036 and 0.08 mm. For the next 2.1 sec., the motion was small, comprising a vibration of T=0.93 sec., 2a=0.019 mm, and a few quick movements (2a=0.019 mm). For the next 7.6 sec. the motion became active, and was composed of the slow vibrations of T=1.12 sec., 2a=0.031 mm, mixed with those of T=0.40 sec., whose maximum (2a=0.045 mm) occurred 9.2 sec. after the earthquake commencement. For the remaining 3.3 sec. of the principal portion, the motion was much smaller: T=0.35 sec., 2a=0.021 mm. The effect of the sound shock was not clear. [End portion.] During the 1st 12.1 sec., the motion was comparatively large and consisted of slow vibrations of T=1.85 sec., 2a=0.0058 mm, divided into movements of half-period and others. Thereafter, the motion was smaller, the T being 0.81 sec. At 4.8 and 6.7 sec. from the commencement of the end portion there took place single sudden quick vibrations, each of 2a=0.010 mm. These might be due to small after-explosions.

(ii) *Tremor-recorder Diagram: Longitudinal and Transverse Components.* The preliminary motion was 0.0019 mm directed away from the crater, accompanied by a slight trace of movement toward the N20° W. The two displacements of the "initial vibration" of 0.036 and 0.08 mm, were combined respectively with those of 0.004 and 0.017 mm in the transverse component, the resultants being 0.036 mm toward the N 63° E and 0.082 mm toward the S 60° W. The maximum slow vibration in the transverse component occurred 2.9 sec. after the earthquake commencement, i.e., its beginning coincided with the end of the "initial vibration" in the longitudinal.

57. *Explosion of July 8th, 1913, at 5. 25. 25 a.m.* This explosion was a little larger than that on the preceding evening. At Yuno-taira there was heard a detonation, which caused shakings of the building, and for 5 sec. could be heard the noises arising from the fall of lava fragments on the slope of the Maikake-yama. At the time, the mountain was shrouded in thick mists.

Tromometer Diagram: Longitudinal Component. Total duration=50 sec. [Preliminary and principal portions: duration=22.5 sec.] The earthquake began with a very small preliminary outward movement of 0.0017 mm (duration=0.29 sec.) and the "initial vibration" of T=1.95 sec. composed of the 1st (inward) and 2nd (outward) displacements respectively of 0.046 and 0.088 mm. For the next 4.4 sec., the motion was small and consisted approximately of 4 irregular vibrations of T=1.11 sec. (max. 2a=0.03 mm) mixed with quick movements of T=0.27 sec., and 2a=0.014 mm. Then took place suddenly a large vibration (absolute maximum) of T=1.41 sec., which was composed of the 1st (inward) and the 2nd (outward) displacements respectively of 0.089 and 0.13 mm. If this maximum motion be supposed to be the effect of the sound shock, the time of its appearance was 6.9 sec. after the earthquake commencement, or 5.7 sec. after the end of the 1st displacement of the "initial vibration." Then there followed 5 others of T=1.05 sec. (max. 2a=0.105 mm), together making up a phase of greatest activity of 6.7 sec. duration. The 2a of the maximum superposed quick vibrations was 0.042 mm. For the remaining 9.1 sec. of the principal portion, the motion was much smaller but nearly uniform, consisting of well defined quick vibrations of T=0.27 sec., and 2a=0.029 mm, mixed with slow movements of T=1.14 sec., and 2a=0.017 mm. [End portion.] Duration=about 27 sec. The motion consisted of regular vibrations of T=0.82 sec., and max. 2a=0.012 mm.

58. ***Explosion of July 13th, 1913, at 4. 01. 19 p.m.*** Since the morning the weather was clear and calm, and the Asama-yama continued perfectly quiet, giving out only a slight amount of white vapours, till the occurrence of the strong explosion in question. The lava fragments projected out with considerable force caused for 20 or 30 minutes conflagrations among the vegetation at the southern slope leading down to the village of Shiono and, at Yuno-taira side, as far down as the vicinity of the observatory, where several patches of the grass-covered ground were set on fire. My assistant, Mr. T. Kato, and the police constable of Komoro, Mr. Ogawa, who were engaged at the time in the search for the rumoured cracks supposed to have been formed on the upper part of the southern side of the Asama-yama, experienced a very narrow escape, having met the explosion at a place only about 1½ km from the top and near the upper boundary of the low tree forest zone. On hearing the detonation, they crept down at once behind a large rock block, when the lava fragments were already falling thickly around them, setting the trees and grasses on fire, while several were projected over their heads with booming noise. The precipitation of the hot stone pieces continued for some time interval, during which the two intrepid men managed alternately to run and to seek shelter behind the trees. The eruption ceased after they had thus changed the place of concealment 3 times successively into the forest. Mr. Ogawa had the good fortune of receiving no injury, although at one time a lava projectile passed between his legs, while Mr. Kato had his toe slightly hit by a small burning rock fragment. The latter gentleman recollects that the detonation was, at the spot where he found himself then, not much louder than the noon-gun in Tokyo heard at the distance of 4 or 5 km, being evidently the shade-effect of the mountain slope. After the explosion, the mountain became again quiet, but threw out large quantity of white smokes.

(i) *Tromometer Diagram: Longitudinal Component.* Total duration=138 sec. [Preliminary and principal portions: duration =26.8 sec.] The preliminary outward motion was 0.002 mm, (duration=0.67 sec.). The 1st, or inward, displacement of the "initial vibration" of T=3.0 sec., was 0.053 mm (duration=1.3 sec.) and free from superposition, while the 2nd, or outward, displacement was 0.123 mm (duration=1.7 sec.) and was mixed in its later course with two small movements, which began to appear 3.4 sec. from the commencement. Then there took place a slow inward displacement of 2a=0.141 mm (duration=5.4 sec.), on which were mixed smaller vibrations of T=1.1 sec., 2a=0.031 mm; at the end there were also some quicker movements, probably denoting the effect of the sound shock which appeared first 8.7 sec. after the commencement of the earthquake, or 6.3 sec. after the end of the 1st displacement of the "initial vibration." The next slow (outward) displacement, of 2a=0.126 mm, lasted 6.3 sec., during which the superposed quick vibrations were most active: T=0.33 sec., 2a=0.053 mm. During the remaining 10.9 sec. of the principal portion the motion was smaller and consisted of quick vibrations of T=0.26 sec., 2a=0.025 mm, mixed with those of T=0.65 sec. [End portion.] The motion was throughout extremely small, consisting, during the 1st 13.1 sec., of minute vibrations of T=0.29 sec., 2a=0.0012 mm, mixed with those of T=0.53 sec., 2a=0.0028 mm, and some others. Thereafter there were also some vibrations of T=0.70 sec.

(ii) *Tremor-recorder Diagram: Longitudinal and Transverse Components.* The very 1st displacement was 0.0022 mm away from the crater, and 0.0018 mm toward N 20° W, giving the resultant motion of 0.0027 mm directed toward N70° W. In the longitudinal component, the preliminary portion lasted 0.64 sec.; while in the transverse, it lasted 2.35 sec. The 1st displacement (=0.053 mm) of the "initial vibration" corresponded to a complete vibration in the transverse component, which consisted of the two movements of 0.0029 and 0.0072 mm. Again, the 2nd displacement of the "initial vibration," which was 0.123 mm, corresponded to a complete vibration in the same component consisting of the two movements of 0.0054 and 0.031 mm. In the transverse component, the maximum vibration of 0.047 mm occurred 8.5 sec. after the earthquake commencement.

59. *Explosion of July 18th, 1913, at 2. 08. 34 a.m.* At Yuno-taira, the observer, Dr. K. Aomi, was aroused from sleep by the detonation. The burning lava fragments which fell on the Maikake-yama were glowing through the mists which surrounded the latter.

Tromometer Diagram: Longitudinal Component. Total duration=148 sec. [Preliminary and Principal portions: duration=25.9 sec.] The diagram is almost perfectly identical with that of the explosion on July 13th. The preliminary motion of 0.0019 mm (duration=0.29 sec.) was followed by the "initial vibration," of T=2.2 sec., composed of the 1st, or inward, displacement of 0.054 mm, and of the 2nd, or outward, one of 0.116 mm. The latter and the succeeding 4½ vibrations of T=0.80 sec., and max. 2a=0.062 mm, may be regarded as together forming a slow oscillation, of T=4.55 sec., and 2a=0.134 mm. Then set in a slow pendulum oscillation of the steady mass, the superposed earthquake motion being active for the next 9.4 sec., and consisting of quick vibrations of T=0.36 sec., 2a=0.050 mm, mixed with those of T=0.78 sec., 2a=0.044 mm. For the remaining

10.4 sec. of the principal portion, the motion was much smaller and composed of the vibrations of T=0.65 sec., 2a=0.026 mm, mixed with some quicker ones. The apparent "sound shock" occurred 6.4 sec. after the commencement of the earthquake, or 5.2 sec. from the end of the 1st displacement of the "initial vibration." [End portion.] At first the motion consisted of vibrations of T=0.60 sec., 2a=0.0036 mm, mixed with traces of slow movements of T=2.3 sec. Later on there were also some other periods.

60. ***Explosion of July 19th, 1913, at 0. 54. 03 p.m.*** The detonation of this strong explosion as heard at Yuno-taira was intensely loud, being, according to the account of the observer, Dr. K. Aomi, like that caused by the simultaneous discharge of several heavy artillery pieces at the immediate vicinity. The eruption sound continued for some 5 minutes after the explosion. The precipitation of the lava fragments was thick; one of these falling on the ground and forming by impact a hole 6 feet in diameter at a distance of 33 metres from the observatory building. Numerous projectiles came down at places several hundred feet below the observatory, which had 4 window panes broken by the shakings of the house. (See p. 13 and Fig. 10.)

(i) *Tromometer Diagram: Longitudinal Component.* Total duration=140 sec. [Preliminary and principal portions: duration=36.9 sec.] The preliminary motion, of 0.0025 mm (duration=0.48 sec.) was followed by the "initial vibration," of T=1.75 sec., composed of the 1st, or inward, displacement of 0.10 mm and the 2nd, or outward, one of 0.127 mm. The latter and the succeeding 4½ vibrations of T=1.28 sec., and max. 2a=0.041 mm, together form a slow oscillation, of T=6.5 sec., and 2a=0.171 mm. The superposed quick vibrations, which may be assumed to represent the "sound shock," began to appear at 6.8 sec. after the commencement of the earthquake, or 5.5 sec. from the end of the 1st displacement of the " initial vibration." These became soon very active (2a=0.077 mm apprx.), when, at 9.9 sec. after the commencement of the earthquake, there took place a large slow displacement of 2a=0.190 mm directed toward the crater followed by a pendulum oscillation of T=14.9 sec., and 2a=0.267 mm. During the last 10.4 sec. of the principal portion, the motion was again active and consisted of extremely quick vibrations of T=0.27 sec., 2a=0.053 mm, distributed into three maximum groups probably due to the precipitation of lava fragments in the vicinity ; the last and largest of the three occurred 35.2 sec. after the earthquake commencement, being no other than the shock caused by the impact of a large lava block some 3 feet in dimension, which fell about 55 metres to the ENE of the observatory. (See § 6). [End portion.] During the 1st 18.6 sec., the motion was composed of small quick vibrations of T=0.45 sec., 2a=0.009 mm, mixed with those of T=1.1 sec. and others. Thereafter, the quick movements disappeared, and the average periods were 1.9 and 1.16 sec.

(ii) *Tremor-recorder Diagram.*

Longitudinal Component. The small preliminary motion was 0.0025 mm directed away from the crater, accompanied by that of 0.0008 mm in the latter directed toward the N20° W, giving the resultant of 0.0026 mm in the direction of S88° W. Corresponding to the 1st, or inward, displacement of 0.10 mm of the " initial vibration " there was in the transverse component a small motion of 0.008 mm directed toward the N20° W, the resultant being 0.10 mm in the direction of N 70° E. Again, corresponding to the 2nd displacement of the " initial vibration," there was a complete oscillation in the transverse component, whose two movements were respectively 0.03 and 0.097 mm.

Transverse Component. The vibrations were comparatively small during the 1st 6.5 sec., with the period of 1.5 sec.; in other words, the maximum phase of motion occurred 6.5 sec. after the commencement of the earthquake. The sudden violent shakings, of max. 2a=0.258 and 0.192 mm respectively in the longitudinal and transverse components, which occurred 34.6 sec. after the earthquake commencement, was probably the effect due to the fall of a large lava block referred to before.

61. *Explosion of Aug. 12th, 1913, at 7. 45. 08 a.m.* The detonation was heard at Yuno-taira, the mountain top being at the time covered by thick mists.

Tromometer Diagram: *Longitudinal Component.* Total duration =120 sec.

The ground was in a trembling condition already from 38.5 sec. before the earthquake: the micro-tremors being composed of the mixture of the vibrations of T=0.57 sec. (max. 2a=0.0015 mm), T=0.26 sec. (max. 2a=0.0096 mm), and some others. [Principal portion: duration=28.8 sec.] The "initial vibration," whose commencement was at $7^h\ 45^m\ 07^s.6$ p.m., and whose period was 1.6 sec., was composed of the 1st, or inward, displacement of 0.029 mm, and the 2nd, or outward, displacement of 0.050 mm. The latter and the succeeding 4½ vibrations (with some superpositions) of T=0.8 sec. together formed a slow oscillation of T=4.5 sec. and of the two displacements of 0.089 and 0.114 mm. This was followed by an outward motion of 0.046 mm (duration=0.48 sec.) mixed with 4 small movements. Then took place a conspicuous vibration of T=1.5 sec., and of the inward and outward displacements of 0.067 and 0.085 mm respectively; there being at the end a well defined superposition of quick movement of 2a= 0.028 mm. For the next 4.55 sec., the motion may be regarded as being made up of slow movements of T=1.14 sec. (max. 2a=0.046 mm), mixed with the quick ones of T=0.38 sec. (max. 2a=0.026 mm). For the next 8.5 sec., the vibrations were regular: T=0.58 sec., max. 2a=0.028 mm. During the remaining 9.1 sec., the motion was much smaller: T=0.7 sec., 2a=0.0113 mm.

62. *Explosion of Aug. 12th. 1913, at 11. 20. 33 p.m.* This was a strong explosion, whose detonation was at Yuno-taira like that of a tremendous thunder peal. The upper part of the mountain was at the time invisible, being enclosed in thick mists. But the glowing lava pieces falling in the vicinity of the observatory looked like groups of shooting stars; one small lava block of the size of a fist falling to within 2 metres distance at the front of the building. (See also p. 14.) In Tokyo, the present author, who was at the time sitting quietly in his house at Koishikawa, by his writing desk, heard the detonation, whose time of occurrence was accurately noted by means of a pocket chronometer to be 11. 26. 58 p.m., (§ 115).

Tromometer Diagram: Longitudinal Component. (See Fig. 54, Pl. XXIII.) Total duration=260 sec.

The preliminary outward motion of 0.0044 mm (duration=0.42 sec.) was followed by the "initial vibration," of T=3.2 sec., which was made up of the 1st, or inward, displacement of 0.125 mm (duration=1.15 sec.), and of the 2nd, or outward, displacement of 0.217 mm (duration=2.0 sec.); the superposition of the small movements appearing first 2.3 sec. from the commencement. For the next 3.8 sec., there were three small vibrations of T=1.2 sec., max. 2a=0.084 mm, (with some superpositions of smaller movements). Then, at 7.6 sec. from the earthquake commencement, or 6.0 sec. from the end of the 1st displacement of the "initial vibration," the writing index of the pointer began for a few seconds to jump up over the smoked paper so that there was left only an imperfect dotted trace of the maximum range of 0.119 mm apprx.. The motion for the next 3.5 sec. probably marks the effect of the sound waves, giving the interval of 6.0 sec. for the time difference between the moments of arrival of the explosive earth motion and the detonation, in perfect accordance with the result obtained from a comparison of the barograph and the tromometer diagrams. The inward motion reached a limit 11.1 sec. after the earthquake commencement, the pointer being thence thrown into the counter displacement of 0.473 mm. Then the pointer was thrown into a large pendulum oscillation, 17.6 sec. in period, composed of the two movements of 0.71 and 0.54 mm respectively. Immediately thereafter, namely, 32.8 sec. from the earthquake commencement, there took place a conspicuous quick vibration of $2a=0.108$ mm, due probably to the impact of a lava mass about $\frac{1}{2}$ metre in dimension, which fell at a distance of only 19 metres to the ENE of the observatory, causing the pointer to deviate again into a large oscillation of $2a=0.46$ mm. The disturbance came practically to end at $11^h\ 21^m\ 12^s$.

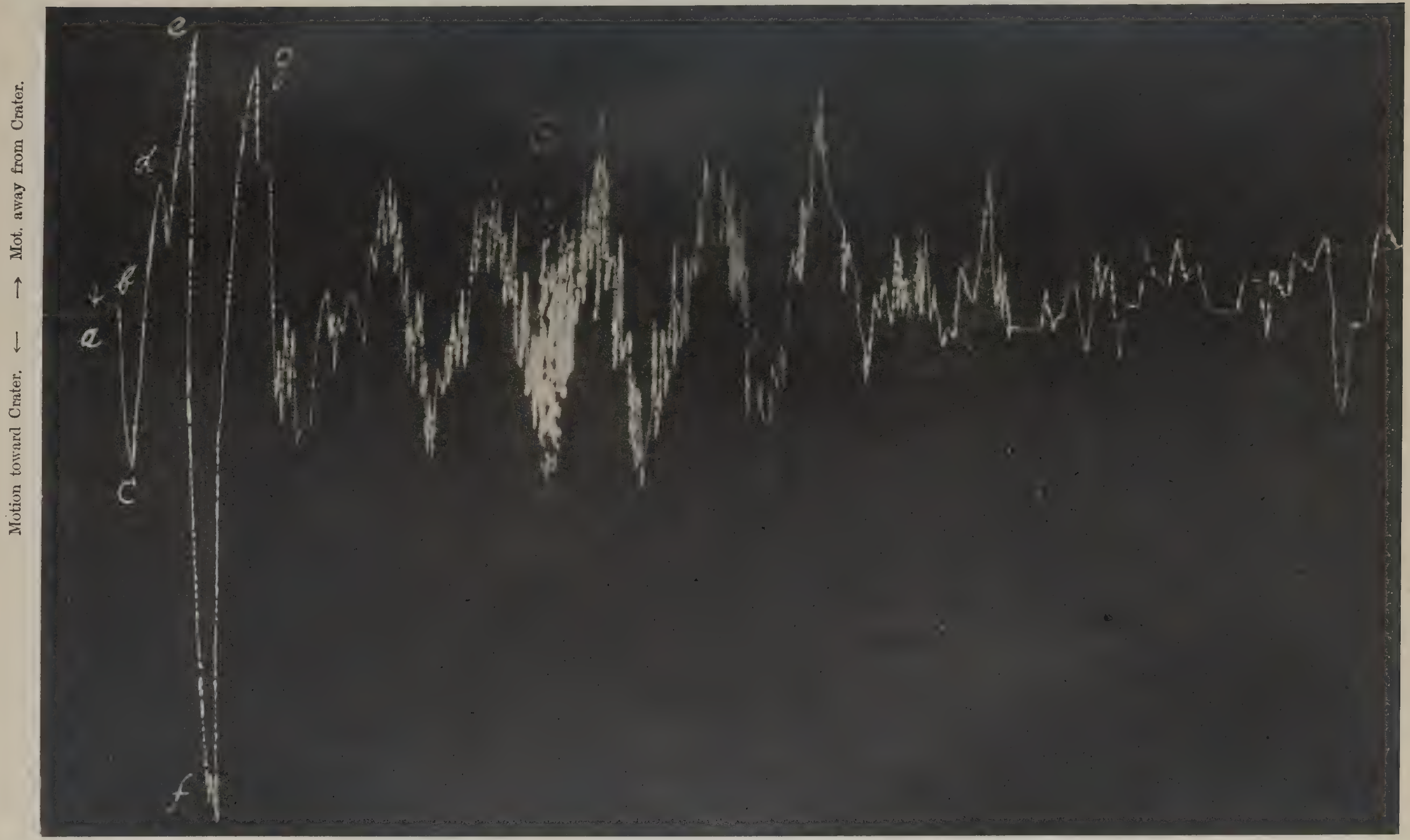
Micro-tremors. The explosion was followed for 19 min. by small micro-tremors, whose max. 2a was 0.0047 mm and whose average period was principally 1.5 sec. apprx. These indicated sudden amplitude increase at irregular intervals and was apparently the results of strong smoke emissions which continued after the outburst.

63. ***Explosion of May 5th, 1914, at 0. 33. 03 a.m.*** According to the report by Mr. Kurosaka, who was in charge of the observatory at Yuno-taira during the 1st half of May, the mountain had been previously quiet, there having been since the beginning of the month neither volcanic earthquakes and tremors nor powerful smoke emissions. Thus the explosion on the 5th occurred abruptly, attended by a tremendous detonation. The noise of the lava fragments striking the slope of the Maikake-yama could be heard for about 5 minutes, although its upper part was at the time shrouded in thick mists; those fallen at the base of the somma sparkling like stars. Ten minutes after, when the sky became clear, white smokes, slightly tinged red, were observed to be thrown out at intervals. On subsequent examination, there was found to be no large lava pieces projected on the Yuno-taira plain.

In Tokyo, the author, who was at the time sitting quietly by a desk with a pocket chronometer before him, in his house (in the Koishikawa district), perceived the detonation at $0^h\ 39^m\ 38^s$ a.m. as a sound like distant gun discharge which shook the *shoji* on the N. side for about $1\frac{1}{2}$ sec. The noise, which, occurring in the depth of night, had a peculiar disturbing effect, was immediately followed by the barking of the dogs and the screaming of the pheasants.

(i) *Tromometer Diagram: Longitudinal Component.* (See Fig. 53.) Total duration$=$171 sec. [Preliminary and principal portions: duration$=$40.6 sec.] The preliminary portion consisted of an outward displacement of 0.004 mm (0.55 sec. in duration). Then followed the "initial vibration," of $T=2.16$ sec., which was composed of the 1st, or inward, displacement of 0.081 mm, and the 2nd, or outward, displacement of 0.143 mm; there being a superposition of three small oscillations of $T=0.7$ sec. For the next 10.5 sec., the motion was made up of $8\frac{1}{2}$ nearly equal and well defined vibrations of $T=1.24$ sec., max. $2a=0.118$ mm; the apparent sound effect, accompanied by the superposition of quick movements of $T=0.4$ sec., appearing 5.4 sec. after the end of the 1st displacement of the "initial vibration." During the remaining 27.5 sec. of the principal portion, the motion was gra-

Fig. 51. Asama-yama Explosion of Sept. 21st, 1913, observed at Asama Pasture Ground.



(Tremor-recorder Diagram.) **Longitudinal Component.** Magnification = 1100. Time Scale: 1 min. = 255 mm.
a....Comm't. bcd....“**Initial Vibration.**” **S....Sound Shock.**

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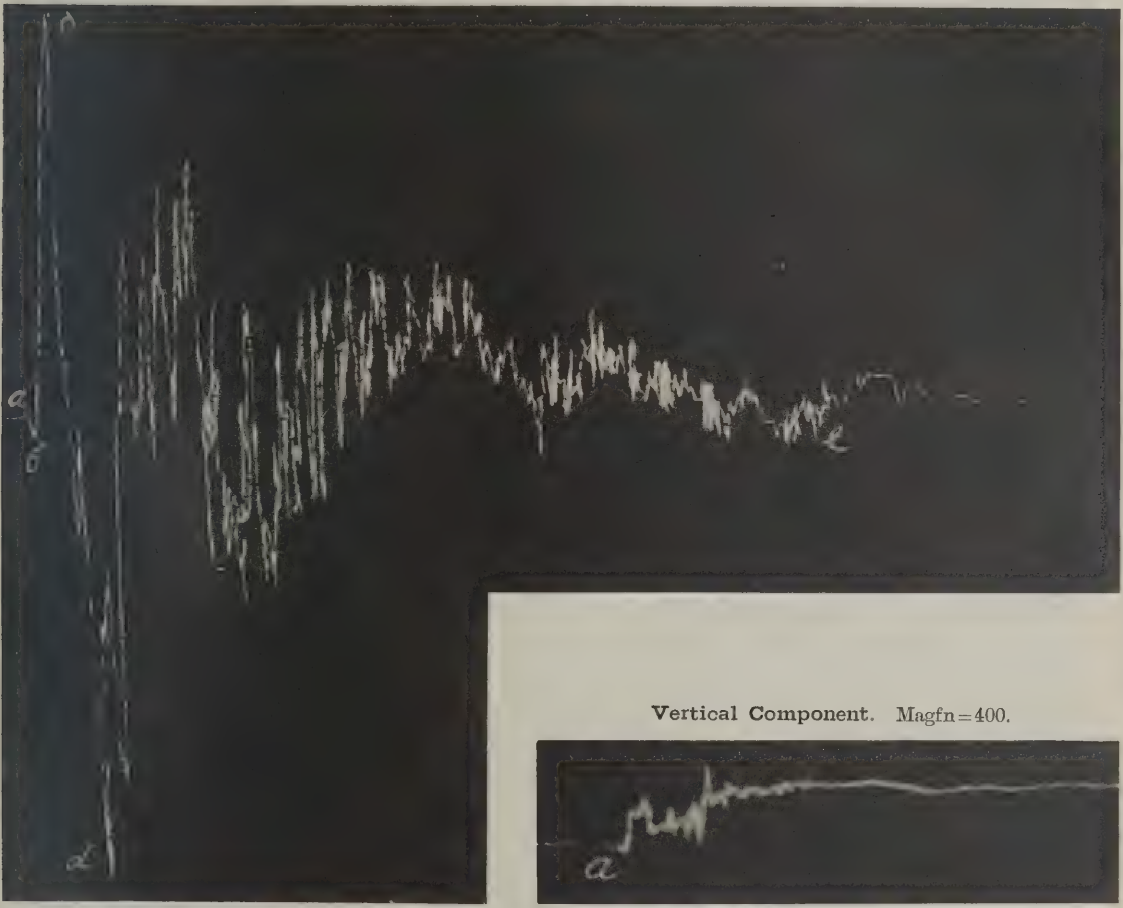
Fig. 52. Asama-yama Explosion of May 29th, 1913, observed at Yuno-taira: Longitudinal and Vertical Components.

a.... Commencement.

Longitudinal Component.
ab.... Preliminary portion.
bcd.... "Initial Vibration."

Magnification = 1160.
Time Scale: 1 minute = 174 mm.



Vertical Component. Magfn = 400.

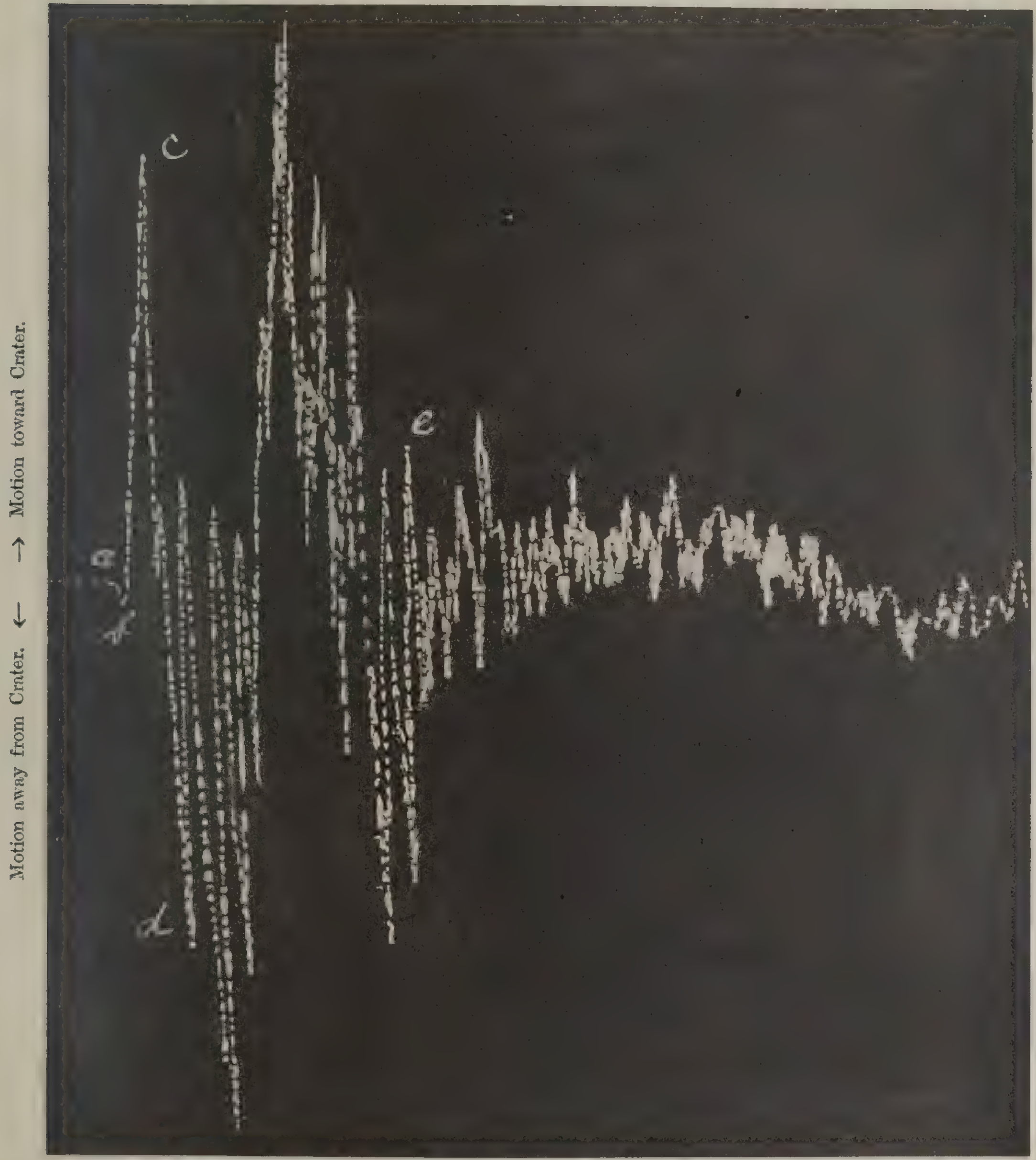
bc.... Motion toward Crater.
cd.... Motion away from Crater.

Time Scale: 1 min. = 98 mm.

OF THE

Pl. XXII.

Fig. 53. Asama-yama Explosion of May 5th, 1914, observed at Yuno-taira; Longitudinal Component.

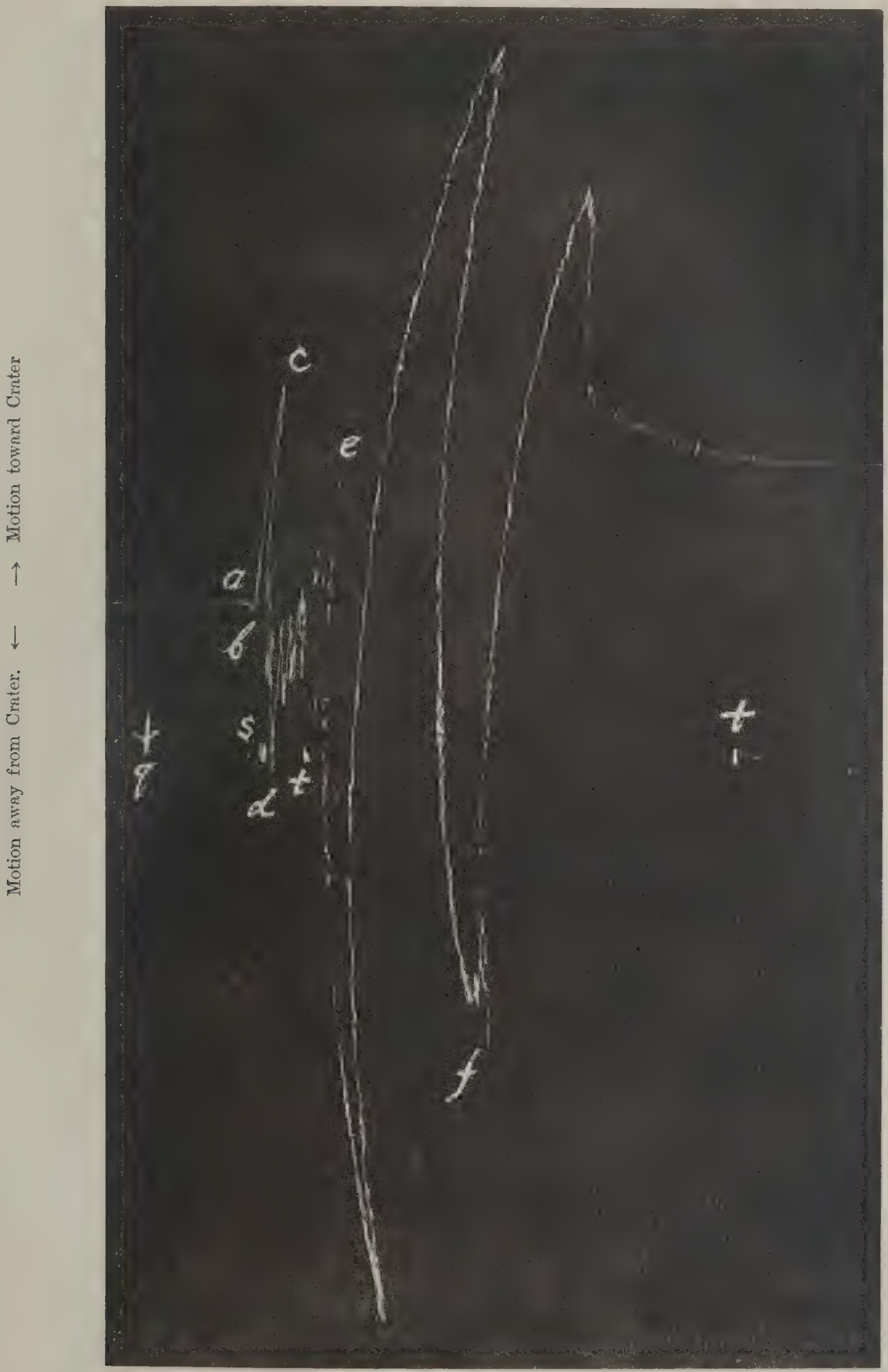


Tromometer Diagram. Magnification = 780. Time Scale: 1 minute = 194 mm.
a....Commencement. bcd .. "Initial Vibration." bc....Most active part.

[illegible]
OF THE
[illegible]

Fig. 54. Asama-yama Explosion of Aug. 12th, 1913, at 11.20.33 p.m., observed at Yuno-taira. Longitudinal Component.

Magnification = 264. Time Scale: 1 minute = 62 mm.



ab....Preliminary Portion. bcd....“Initial Vibration.” tt ....Minute Time Marks.
f ....Shakings caused by falling stones. s ....Mark made by the observer by pushing electric key when he was aroused from sleep by the detonation. q ....Time corresponding to Commencement.

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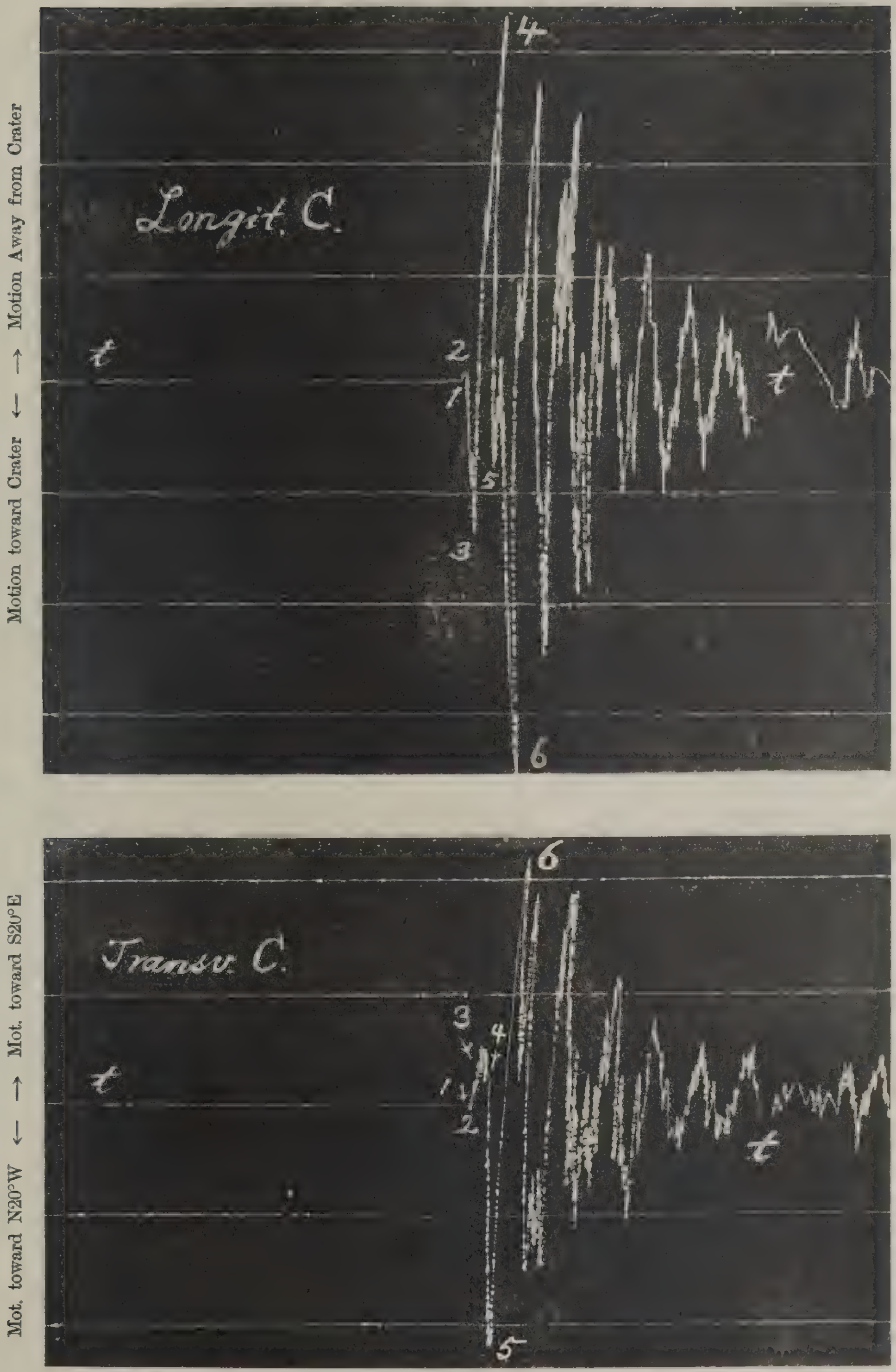
Pl. XXIV.

Fig. 55. Asama-yama Explosion of May 5th, 1914, observed at Yuno-taira.



(Tremor-recorder Diagram.) Magnification = 365. Time Scale: 1 minute = 96 mm.
t, t . . . . Successive Minute Cuttings. 1 . . . . Commencement.
1, 2, 3, 4, 5, ... Corresponding parts in the two components.

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dually reduced from 0.046 to 0.011 mm, the quick vibrations being mixed with those of T=1.26 sec.: Duration of the specially active part=12.7 sec. In the later part of the *end portion* the vibrations were regular, T=1.12 sec.

(ii) *Tremor-recorder Diagram.* In Fig. 55 are reproduced the longitudinal and transverse component tremor-recorder diagrams, with the resultant magnification of 365, and the time scale of 96 mm for 1 minute. As the writing indices of the pointers were simultaneously lifted every minute, a given time moment can be identified with perfect accuracy in the two different directions. The preliminary motion, of duration of 0.6 sec., was composed of the following displacements:—0.0035 mm, away from the crater; 0.0009 mm, towards N 20 W; resultant motion=0.0036 mm, toward S 85° W. The 1st displacement of the "initial vibration" in the longitudinal component was 0.063 mm, toward the crater, accompanied by a displacement of 0.018 mm toward S20° E, giving the resultant motion of 0.065 mm directed toward the N86° E. The 2nd displacement of the "initial vibration" was 0.203 mm, directed away from the crater and was accompanied by a small complete oscillation of 2a=0.012 mm, being thus almost perfectly radial in direction. In the transverse component, there followed the maximum slow oscillation of T=2.2 sec., composed of the two displacements corresponding to the largest well defined ones in the longitudinal component, as follows:—

1st displacement .. 0.108 mm, toward N 20° W,
0.176 ,, , ,, Crater;
Resultant motion= 0.206 mm, directed toward N40° E.

2nd displacement.. 0.192 mm, toward S 20° E.
0.162 ,, , toward Crater.
Resultant motion= 0.251 mm, directed toward S 20° W

The maximum and 1st well-defined transverse vibration occurred 1.8 sec. later than the longitudinal "initial vibration."

CHAPTER VII. NON-EXPLOSIVE ERUPTIONS OBSERVED AT YUNO-TAIRA AND THE ASAMA PASTURE GROUND.*

64. ***Eruption of June 24th, 1913, at 11. 34. 17 p.m.*** At Yuno-taira, there was perceived some sound, accompanied by the slight shakings of the building. As the mountain was shrouded in thick mists, the condition of the crater could not be ascertained.

Yuno-taira Tromometer Diagram: Longitudinal Component. Total duration=88 sec.

[Preliminary and principal portion: duration=21.1 sec.] Unlike the diagrams in the usual cases, the motion began with a very small "initial vibration," of T=2.7 sec., composed of the 1st, or inward, displacement of 0.001 mm, and the 2nd, or outward, one of 0.0034 mm. For the next 6.2 sec., the motion was largest, being composed of the 4 nearly equal vibrations of the average T=1.55 sec., max. 2a=0.0305 mm, mixed with the quick movements of T=0.30 sec., 2a=0.0164 mm; the quivering of the writing pointer due to the sound shock, occurring 5.5 sec. after the end of the 1st displacement of the "initial vibration." During the next 4.5 sec., the motion was smaller and consisted of vibrations of T=1.0 sec., 2a=0.016 mm, mixed with those of T=0.45 sec., 2a=0.0085 mm. During the remaining 7.6 sec. of the principal portion, the vibrations were small: T=0.9 sec., max. 2a=0.0077 mm. [End portion.] The motion was regular: T=0.64 sec., max. 2a=0.0039 mm.

65. ***Eruption of July 1st, 1913, at 0. 17. 01 p.m.*** At Yuno-taira, the eruption was announced by very faint sounds like those of distant thunders, causing the building to be shaken gently. At the same time, black smokes were just appearing upon the top of the Maikake-yama, this time moment being 14 sec. later than the commencement of the earthquake motion as registered by the tromometer. 2 or 3 sec. after there were heard the noises caused by the falling of the lava fragments on the upper part of the somma. A picture of this eruption seen from Yuno-taira is given in Fig. 4.

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* The times of occurrence of the eruptions considered in this chapter are those registered at Yuno-taira, with the exception of the last case, for which the observation was made only at the Asama Pasture Ground.

(i) *Yuno-taira Tromometer Diagram: Longitudinal Component.* (Fig. 56.) Total duration=150 sec.

The diagram indicates a well defined preliminary tremor, and consists, unlike those due to the explosions, of the slow vibrations mixed with a comparatively slight amount of the quicker movements. [Preliminary tremor.] Duration=2.3 sec. The motion was composed of small regular vibrations of T=0.31 sec., 2a=0.0004 mm, mixed with slow ones of T=0.99 sec., 2a=0.001 mm. [Principal portion.] Duration=13.4 sec. The "initial vibration" was composed of the 1st, or inward, and the 2nd, or outward, displacements respectively of 0.0097 and 0.043 mm, the period being 2.0 sec. The next vibration was small: T=1.23 sec., 2a=0.023 mm. The 3rd vibration was again much larger; T=1.54 sec., 2a=0.048 mm. So far there was practically no superposition of quick movements. These latter became, however, prominent (max. 2a=0.022 mm, T=0.27 sec.) during the next 4.8 sec., which interval may be regarded as forming the most active part of motion, and which began with a marked (slow period) displacement of 0.044 mm directed toward the origin. During the remaining 4.03 sec. of the principal portion, the motion was much smaller, being composed of slow vibrations of T=1.19 sec., 2a=0.013 mm, with slight superpositions of small movements. The effect due to the sound shock was not clearly indicated. [End portion.] The motion was made up of slow vibrations of T=1.24 sec., max. 2a=0.0041 mm, mixed with small movements of T=0.44 sec., and T=0.58 sec. (max. 2a=0.0015 mm).

(ii) *Yuno-taira Tremor-recorder Diagram: Transverse Component.* The principal portion lasted 13.2 sec. and consisted of 9 regular vibrations of T=1.4 sec., the maximum (absolute) motion of 0.044 mm occurring 3.8 sec. after the commencement of this phase. In the end portion the vibrations of T=1.35 sec. (2a=0.004 mm) were mixed with those of T=0.62 sec.

66. *Eruption of Aug. 13th, 1913, at 4. 01. 19 p.m.* The rushing sounds of the eruption were heard at Yuno-taira for about 15 minutes. Throughout the day strong winds continued to blow, and the mountain was enclosed in thick mists.

Yuno-taira Tromometer Diagram: Longitudinal Component. Total duration=80 sec.

[Premonitary Eruption.] At 4. 01. 05 p.m. there took place a small earthquake caused by a premonitary eruption. After the preliminary portion of 1.5 sec. duration, there set in, for the next 3.7 sec., three well-defined vibrations of T=1.2 sec., max. 2a=0.0027 mm, mixed with minute movements of T=0.23 sec. For the next 3.6 sec., the motion was smaller: T=0.77 sec., 2a=0.0017 mm. For the next 5.0 sec., the motion became still smaller, indicating traces of oscillations of T=0.94 sec. Then took place the preliminary portion of the [Main Eruption], which lasted 3.2 sec. and consisted of small regular vibrations of T=0.23 sec., max. 2a=0.0013 mm. The principal portion, which lasted 13.1 sec., and consisted of slow movements with only insignificant mixture of quick tremors, was introduced by a vibration of T=1.08 sec.

composed of the two displacement of 0.0052 and 0.012 mm respectively. The next vibration, whose period was 1.45 sec., had the maximum (absolute) 2a of 0.023 mm. For the next 3.2 sec., there were 4 smaller vibrations of T=0.8 sec., max. 2a=0.015 mm, grouped into those of double period. During the remaining 7.6 sec. of the principal portion, there were 7 vibrations of T=1.1 sec., a max. 2a of 0.021 mm occurring at the commencement of this phase. Thereafter the motion became much smaller and was composed chiefly of two sets of vibrations whose mean periods were as follows:—

T=0.76 sec.	(2a=0.0059 mm)	T=1.08 sec.	(2a=0.0037 mm)
0.82		1.35	(2a=0.0021 ,,)
0.77		1.50	

The period of the superposed small movements were 0.23 and 0.36 sec. The total duration of the two disturbances was over 80 sec.

67. *Eruption of Aug. 15th, 1913, at 9. 59. 11 a.m.* This eruption as well as the two others in the afternoon consisted in a very powerful emission of black smokes, which were seen also from the city of Nagano. On these occasions small platy lava fragments, of maximum weight of 16 grams were precipitated in great abundance at the base of the Ko-Asama. In the 2nd and 3rd eruptions, the sounds like those of billows of sea were heard at Yuno-taira for a few minutes. In Fig. 6 is given a view of the eruption in the morning taken from the Yuno-taira observatory.

Yuno-taira Tromometer Diagram: Longitudinal Component. The eruption was preceded by a volcanic earthquake, the total duration of the premonitary non-eruptive earthquake and the eruption effect being 3 min. The earthquake began, at 9. 59. 11 a.m. with a short preliminary tremor composed of a single small vibration of 0.0014 mm and of duration of 0.44 sec. The principal portion lasted 1.8 sec., and was made up entirely of very quick vibrations of max. 2a=0.0497 mm. The subsequent motion was very small and composed of the vibrations of T=0.91 sec., mixed with those of T=0.35 sec.

For $6^m\ 28^s$ before the above-mentioned earthquake, the ground was making small slow vibrations of T=1.3 sec., max. 2a=0.0005 mm.

For 23.8 sec. after the earthquake, there were slight vibrations similar to those which existed previous to the latter. For the next 26.6 sec., the movements became more marked: T=1.2 sec., max. 2a=0.0008 mm, mixed with the tremors of T=0.39 sec. These probably formed the precursors of the eruption whose earthquake effects became larger during the next 30.0 sec., the motion consisting of vibrations of T=1.35 sec., max. 2a=0.004 mm, mixed with the smaller ones of T=0.73 sec., and still shorter ones. Then the motion bocame suddenly large, and there were, during the next 3.4 sec., an outward displacement of 0.009 mm, followed by 2 nearly equal conspicuous vibrations of T=1.34 sec., max. 2a=0.021 mm. Thereafter the motion decreased and, for the next 40.2 sec., was composed of the vibrations of T=1.18 sec., max. 2a =0.009 mm, mixed with some smaller ones. The subsequent vibrations were much smaller: T=1.27 sec. Till $10^h\ 10^m$ p.m. the ground continued to execute a sort of minute movements similar to those which existed before the premonitary earthquake.

68. ***Eruption of Aug. 15th, 1913, at 3. 58. 46 p.m.*** *Yunotaira Tromometer Diagram: Longitudinal Component.* Total Duration=$3^m\ 25^s$. The motion began gradually and consisted, for the 1st 47.7 sec., of regular vibrations of T=1.3 sec., max. 2a=0.0024 mm mixed with small movements of T=0.42 sec., and T=0.61 sec., max. 2a=0.0023 mm. Thereafter the motion became larger and nearly free from the superposition of the latter, being, for the next 28.7 sec., composed of the vibrations of T=1.9 sec., max. 2a=

0.0067 mm mixed with smaller ones. The subsequent motion was gentle and gradually decreased: T=1.8 sec., max. 2a=0.0019 mm, mixed occasionally with the small ones of T=0.97 sec.

69. *Eruption of Aug. 15th*, 1913, *at* 5. 08. 54 *p.m.* *Yunotaira Tromometer Diagram: Longitudinal Component.* Total duration=60 sec. apprx. The preliminary motion lasted about 2.0 sec. and was very small. The principal portion, which lasted 25 sec., began with the slow "initial vibration" of T=2.1 sec., composed of the 2 displacements of 0.010 and 0.034 mm (absolute maximum) respectively. During the next 9.1 sec., there were 8 vibrations of T=1.14 sec., whose 2a gradually decreased from 0.026 to 0.0038 mm; of these the 1st two only being mixed with small movements (T=0.24 sec. apprx., 2a=0.011 mm). During the remaining 13.8 sec. of the principal portion, the amplitude remained on the whole constant, the motion being composed of the vibrations of T=0.71 sec., max. 2a=0.0033 mm, grouped into the slower ones of T=1.27 sec., max. 2a=0.0047 mm. Thereafter the motion became much smaller, and consisted for the next 37.1 sec. of the vibrations of T=0.67 sec., T=1.04 sec., and T=1.25 sec., mixed with tremors of T=0.27 sec. Then the vibrations again gradually increased up to 2a of 0.0036 mm, on account of the renewed eruptive activity. The ground executed minute vibrations almost continuously till about 5.21 p.m.

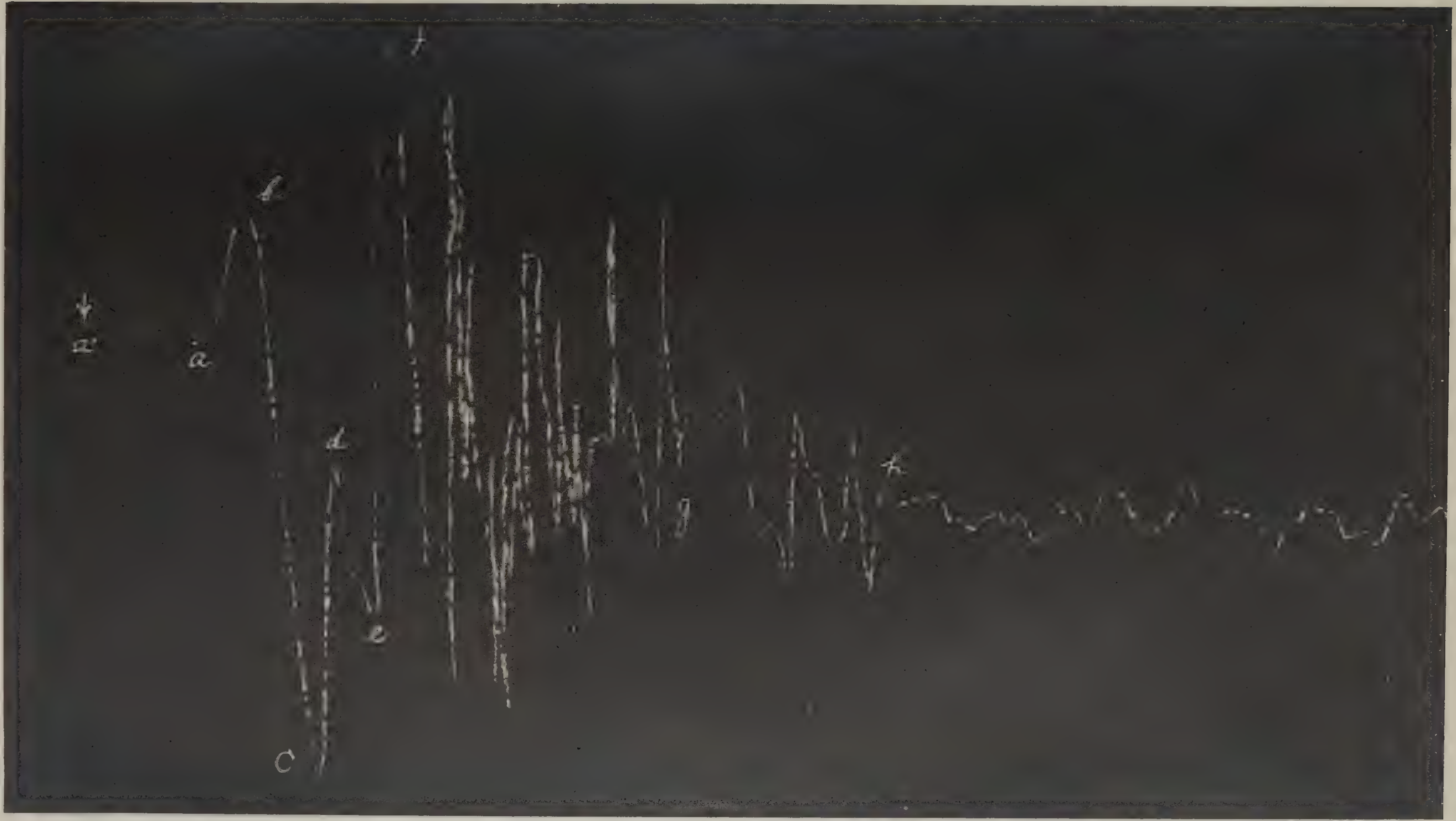
70. *Eruption of Nov. 20th*, 1913, *at* 3. 40. 35 *p.m.* (Fig. 50.) *Tremor-recorder Diagram at the Asama Pasture Ground.* Total duration=110 sec.

Longitudinal Component. [Preliminary and principal portions: duration=61 sec.] The motion was very small during the 1st 0.9 sec., after which took place the "initial vibration" of T=2.5 sec., composed of the 1st and 2nd displacements of 0.005 and

0.019 mm respectively. For the next 6.6 sec., there were two oscillations of nearly equal amplitude (max. 2a=0.053 mm) of T=3.3 sec.; the moment of appearance of the superposed quick vibrations (T=0.26 sec., max. 2a=0.032 mm) being 5.6 sec. after the earthquake commencement, or 3.6 sec. after the end of the 1st displacement of the "initial vibration," and coinciding with the occurrence of the eruptive phase which gave rise to the barometric disturbance. (See Chapter XIII.) For the next 4.8 sec., there were 2 large oscillations of T=2.4 sec., the max. (absolute) displacement of 0.21 mm occurring 12.3 sec. after the commencement. During the next 10.7 sec., the motion was smaller and composed of the vibrations of T=0.82 sec., max. 2a=0.062 mm, mixed as before with quick vibrations. Thereafter the latter almost entirely disappeared, and the motion remained nearly constant during the remaining 36 sec. of the principal portion, being composed of the vibrations of T=1.06 sec., max. 2a=0.048 mm, mixed more or less distinctly with slow oscillations of T=3.3 sec. [End portion.] The vibrations were small: T=1.2 sec., max. 2a=0.011 mm.

Transverse Component. [Preliminary and principal portions: duration=72 sec.] The motion was practically *nil* during the 1st 2.5 sec., after which a small left-hand side displacement of 0.0028 mm took place, followed by a vibration of T=2.2 sec., 2a=0.040 mm. For the next 4.3 sec., the motion was also small (max. 2a=0.051 mm, T=1.4 sec.); there appearing, however, the superposition of quick movements of T=0.18 sec., max. 2a=0.011 mm. Then took place a large oscillation of T=1.84 sec., whose 2nd displacement had the max. (absolute) 2a of 0.146 mm, and occurred 10.9 sec. after the earthquake commencement. For the next 5.6 sec., the motion was active and composed of 6 vibrations of T=0.93 sec., max. 2a=0.10 mm, with the superposition of

Fig. 56. Non-detonative Eruption of Asama-yama on July 1st, 1913, observed at Yuno-taira.



Longitudinal Component. Magfn = 2000. Time Scale: 1 min. = 455 mm. a'....Commencement. a'a....Preliminary portion. eg....Most active part. ah....Principal portion. ab.... 1st displacement of the "initial vibration," abc, directed toward the crater.

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quick movements of T=0.20 sec. For the next 12.3 sec., the vibrations, which were free from the mixture of small movements, were perfectly regular: T=1.07 sec., max. 2a=0.094 mm. During the rest of the principal portion, the motion was much smaller: T=1.03 sec., max. 2a=0.038 mm. [End portion.] The vibrations were very small: T=1.3 sec., max. 2a=0.012 mm.

Comparison of the Longitudinal and Transverse Components. The preliminary small portion lasted 1.6 sec. longer in the transverse than in the other component, so that the 1st displacement of the "initial vibration" was entirely longitudinal: the resultant 2nd displacement (2a=0.019 mm) being directed away from the crater with the westward deviation of 8° from the radius. The maximum motion phase set in 10.0 sec. after the commencement in each component. During the 1st 14.6 sec. of the earthquake, the motion was greater in the longitudinal than in the transverse component. But thereafter vibrations were much more conspicuous in the latter than in the former, the max. 2a's in the two components being in the ratio of 15 to 10.

CHAPTER VIII. VOLCANIC MICRO-TREMORS AND SMALL NON-EXPLOSIVE ERUPTIONS OBSERVED AT YUNO-TAIRA, 1911—1912.*

71. *Volcanic micro-tremors and eruptions on Oct. 2nd, 1912.*

Tromometer Diagram: Longitudinal Component. (Figs. 57 and 58.) The first 154 eruptions, which occurred between 11. 22. 40 a.m. and 1. 04. 27 p.m., were small and of the simpler type. Thereafter the eruptions, though still of small magnitude, happened in close succession, so that the diagram indicated, for the next $1^{h}\,59^{m}\frac{1}{3}$ a continuous series of the volcanic micro-tremors. From about 3. 03. 45 p.m., the shocks, most of which were of complex type, became again individually distinct, some of the greatest occurring at 3. 54. 22 ; 3. 58. 59 ; and 6. 48. 12 p.m. The explosions became gradually fewer, finally ending with the one at 8. 44. 52 p.m. Thus it will be seen that the eruptions on the day in question lasted altogether about $9\frac{1}{3}$ hours.

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* The times of occurrence of the different outbursts considered in this chapter are those registered by the tromometer at Yuno-taira.

(i.) The elements of motion of the continuous "*volcanic micro-tremors*" were as follows :—

T (sec.)	2a (mm)	T (sec.)	2a (mm)	T (sec.)	2a (mm)
1.26	0.0037	0.29	0.0025	0.83	0.0044
1.30	42	0.27	17	1.23	56
1.32	42	0.84	60	1.24	67
0.95	31	0.85	47	0.50	47
0.97	34	0.45	21	0.55	36
0.49	17	1.00	27	1.19	39
0.92	37	0.96	33	0.32	09
1.17	89	1.18	42	1.32	47
1.29	68	0.46	14	0.82	49
0.94	55	0.38	09	0.32	17
0.88	57	0.34	17	0.49	41
0.93	67	0.95	46		

(ii.) The elements of motion of some of the typical *eruptions in the 1st stage*, or those which occurred previous to the appearance of the micro-tremors were as follows.

Eruption of 11. 59.05 a.m. A very small shock. Total duration $=29$ sec. [Preliminary portion.] Duration$=4.5$ sec. [Principal portion.] Duration$=9.0$ sec. $T=0.40$ sec., $2a=0.001$ mm.

Eruption of 0. 20. 09 p.m. Total duration$=28$ sec. During the first 4.5 sec. of the principal portion, the vibrations were largest : $T=1.32$ sec., $2a=0.005$ mm. The subsequent portion was made up of vibrations of T=1.03 sec., mixed with the quicker ones.

Eruption of 0. 21. 02 p.m. [Preliminary portion.] Duration=4.3 sec. [Principal portion.] Duration=9.4 sec. T=0.46 sec., 2a=0.001 mm; T=0.64 sec., 2a=0.0008 mm.

Eruption of 0. 42. 13 p.m. [Preliminary portion.] Duration=4.7 sec. T=0.46 sec.; T=0.72 sec., 2a=0.0008 mm. [Principal portion.] Duration=14.4 sec. T=0.36 sec., 2a=0.0026 mm; T=0.70 sec., 2a=0.005 mm. At first, there were traces of slow movements of T=1.7 sec.

Eruption of 0. 42. 35 p.m. [Preliminary portion.] Duration=5.4 sec. T=0.82 sec., 2a=0.0008 mm. [Principal portion.] Duration=11.6 sec. T=1.35 sec., 2a=0.009 mm; T=0.57 sec., 2a=0.004 mm., mixed with some quicker movements. [End portion.] T=1.27 sec., 2a=0.0033 mm; T=0.40 sec., 2a=0.0017 mm.

Eruption of 1. 02. 36 p.m. [Preliminary portion.] Duration=5.6 sec. T=1.06 sec., T=0.52 sec., 2a=0.0004 mm. [Principal portion.] Duration=8.4 sec. T=1.39 sec., 2a=0.005 mm; mixed with small vibrations of T=0.42 sec. [End portion.] T=0.56 sec., 2a=0.0014 mm.

(**iii.**) The elements of motion of some of the typical *eruptions in the 3rd stage*, or those which occurred subsequent to the appearance of the micro-tremors, were as follows.

Eruption of 3. 32. 27 p.m. [Principal portion.] Duration=9.0 sec. T=1.27 sec., max. 2a=0.018 mm (2nd vibration), mixed with quick movements of T=0.40 sec.

Eruption of 3. 33. 33 p.m. [Preliminary portion.] Duration=4.2 sec. [Principal portion.] Duration=18.6 sec. In the 1st 5.5 sec., the motion was simple and made up of 5 slow vibrations of T=1.10 sec., 2a=0.0068 mm, the superposed movements being insignificant. In the remaining part of this phase, the motion consisted of the vibrations of T=1.04 sec., 2a=0.011 mm, mixed with quick ones of T=0.35 sec., 2a=0.0041 mm. [End portion.] T=0.58 sec., mixed with slower movements.

Eruption of 3. 54. 22 p.m. This was the largest disturbance which occurred on Oct. 2nd. [Preliminary portion.] Duration=5.6 sec. T=0.56 sec., 2a=0.0012 mm. [Principal portion.] Duration=9.0 sec. In the 1st 3.8 sec., there were three slow vibrations of T=1.27 sec. of gradually increasing amplitude, the 3rd having the max. 2a of 0.027 mm. In the remaining 5.2 sec. of this phase, the motion was made up of well defined quick vibrations of T=0.52 sec., the 1st two of which had the greatest 2a's respectively of 0.0246 and 0.0241 mm. [End portion.] T=0.53 sec., 2a=0.0049 mm; T=0.92 sec., 2a=0.0041 mm.

Eruptions of 3. 55. 03 and 3. 55. 18 p.m. In the principal portion of these two successive shocks, lasting together 23.2 sec., the motion was composed chiefly of the following vibrations:

T (sec)	2a (mm)	T (sec.)	2a (mm)	T (sec.)	2a (mm)
0.33	0.0081	0.58	0.010	1.04	0.0076
0.31	0.0078	0.47	0.011		

Eruption of 3. 55. 39 p.m. [Principal portion.] Duration=8.1 sec. T=0.36 sec., 2a=0.013 mm; T=0.89 sec. (2a small).

Eruption of 3. 55. 52 p.m. [Principal portion.] Duration=10.6 sec. T=0.92 sec., 2a=0.013 mm; T=0.41 sec., 2a=0.0068 mm.

Eruption of 3. 56. 06 p.m. [Principal portion.] Duration=8.0 sec. The motion was composed chiefly of well defined quick vibrations of T=0.36 sec., 2a=0.013 mm, which were mixed with slower movements.

Eruption of 4. 15. 54 p.m. Total duration=28 sec. [Preliminary portion.] Duration=6.9 sec. T=0.40 sec., 2a=0.0009 mm. [Principal portion.] Duration=5.7 sec. The motion consisted almost entirely of quick vibrations of T=0.44 sec., 2a=0.01 mm. [End portion.] T=0.46 sec., 2a=0.0030 mm.

Eruption of 4. 18. 56. p.m. Total duration was over 29 sec. [Preliminary portion.] Duration=8.8 sec. T=0.89 sec., 2a=0.0009 mm; mixed with some smaller vibrations. [Principal portion.] T=0.53 sec., 2a=0.003 mm; T=1.1 sec.

Eruption of 5. 00. 37 p.m. Total duration=44 sec. [Preliminary portion.] Duration=7.0 sec. [Principal portion.] For the 1st 6.1 sec., the motion was composed chiefly of the vibrations of T =0.58 sec., 2a=0.004 mm. Thereafter the motion consisted of regular movements of T=0.48 sec., 2a=0.0025 mm, and remained almost uniform in amplitude till the end of the earthquake. The character of motion thus suggests the case of a small but steady smoke eruption which continued for some 30 or 40 seconds. The two following earthquakes were of the same type.

Eruption of 5. 06. 36 p.m. Total duration=35 sec. [Preliminary portion.] Duration=6.6 sec. apprx. [Principal portion.] Duration =15.0 sec. In the 1st 3.8 sec., the motion was comparatively small: T=0.36 sec., 2a=0.0034 mm. In the remaining 11.2 sec., the vibrations were perfectly regular: T=0.48 sec., 2a=0.009 mm. [End portion.] T=0.46 sec.

Eruption of 5. 07. 08 p.m. [Principal portion.] Duration=12.8 sec. T=0.47 sec., 2a=0.004 mm.

Eruption of 6. 48. 12 p.m. Total duration=50 sec., apprx. [Preliminary portion.] Duration=3.5 sec. [Principal portion.] Duration=10.4 sec. In the 1st 8.2 sec., the motion was made up of 6 slow vibrations, which gradually increased in amplitude till the 5th one: T=1.37 sec., max. 2a=0.03 mm. Thereafter the vibrations were: T=0.55 sec., 2 a=0.0125 mm. [End portion.] T= 1.01 sec.

72. *Eruption of July 1st, 1911, at* 11. 32. 08 *a.m.* Total duration=60 sec. *Longitudinal Component.* [Prelim. portion.] Duration=6.0 sec. T=0.83 sec., 2a=0.0014 mm. [Principal portion.] Duration=15.0 sec. T=0.80 sec., 2a=0.01 mm. [End portion.] T=0.78 sec., 2a=0.0031 mm. *Transverse Component.* [Prelim. portion.] Duration=4.8 sec., 2a=0.004 mm, T=1.2 sec. apprx. [Principal portion.] Duration=14.6 sec. The motion consisted of vibrations of T=1.25 sec., 2a=0.014 mm, mixed with quicker movements of T=0.54 sec. [End portion.] T=0.67 sec., 2a=0.0042 mm.

73. *Eruption of July 2nd, 1911, at* 2. 18. 23 *p.m.* Total duration=40 sec. *Longitudinal Component.* [Prelim. portion.] Duration=3.7 sec. [Principal portion.] Duration=14.6 sec. The motion consisted of comparatively slow vibrations of T=0.90 sec., 2a=0.015 mm, mixed with quick movements of T=0.38 sec. [End portion]. The vibrations were regular: T=0.82 sec., 2a=0.0023 mm, there being at first also small quick movements of T=0.40 sec. Toward the very end, there were some traces of slow movements of T=2.6 sec. *Transverse Component.* [Prelim. portion.] Duration=5.3 sec. [Principal portion.] Duration=12.8 sec. The motion was regular: T=0.80 sec., 2a=0.012 mm. [End portion.] T=0.88 sec., 2a=0.005 mm.

74. *Eruption of July 8th, 1911, at* 10. 16. 04 *a.m.* Total duration=50 sec. *Longitudinal Component.* [Preliminary portion.] Duration=5.5 sec. [Principal portion.] Duration=11.5 sec. T=0.75 sec., max. 2a=0.031 mm. [End portion.] T=0.74 sec., 2a=0.007 mm. *Transverse Component.* [Preliminary portion.] Duration=4.2 sec. [Principal portion.] Duration=8.8 sec. T=0.77 sec., 2a=0.03 mm. [End portion.] T=0.72 sec., 2a=0.006 mm.

75. *Eruption of July 14th, 1911, at* 4. 32. 26 *a.m.* *Longitudinal Component.* Total duration=60 sec. [Preliminary portion.] Duration=5.5 sec.: 2a=0.0009 mm, T=0.92 sec., T=1.4 sec. [Principal portion.] Duration=9.5 sec. Motion was regular, max. 2a=0.015 mm, T=0.95 sec. [End portion.] Motion gradually decreased: max. 2a=0.0036 mm, T=0.74 sec. *Transverse Component.* [Preliminary portion.] Duration=18.2 sec., 2a=0.0033 mm, T=1.4 sec. Principal portion.] Duration=8.7 sec. Motion was regular: max. 2a=0.02 mm, T=0.79 sec. [End portion.] T=1.0 sec.

76. ***Eruption of July 21st, 1911, at 10. 47. 40 p.m.*** Total duration=35 sec. *Longitudinal Component.* [Preliminary portion.] Duration=2.3 sec. T=0.8 sec. [Principal portion.] Duration=18.6 sec. During the 1st 11.2 sec., the motion consisted of comparatively slow vibrations of T=1.32 sec., 2a=0.023 mm, mixed with those of half period. During the rest of this phase, there predominated quick movements of T=0.43 sec., 2a=0.0095 mm, mixed with slower ones of T=1.03 sec. [End portion.] T=0.76 sec., 2a=0.0036 mm. *Transverse Component.* [Preliminary portion.] Duration=3.4 sec., T=0.78 sec., 2a=0.0035 mm. [Principal portion.] Duration=15.0 sec. The motion was composed of the vibrations of T=0.72 sec., 2a=0.016 mm, mixed with some slower ones. [End portion.] T=0.91 sec., 2a=0.0036 mm; T=0.58 sec.

77. ***Eruption of Aug. 15th, 1911, at 4. 42. 50 a.m.*** This was a small outburst, which projected out stones and killed one police constable and an American missionary who were then sitting at the crater edge.* From Fig. 61, which is a photographic enlargement (magnification=630) of the longitudinal component of the tremor-recorder diagram, the eruption seems to have been followed at close intervals by at least three minor ones, making up the total duration of about $1^m\ 40^s$. In the principal, or first, eruption the preliminary portion lasted 2.8 sec. During the first 8.8 sec. of the principal portion, the motion consisted of vibrations of T=1.5 sec., 2a=0.013 mm, divided into those of half period. During the remaining 10.4 sec. of the same phase, the motion was principally as follows:—T=1.1 sec., 2a=0.025 mm. The period of the regular vibrations in the end portion of the series of the different shocks was about 0.80 sec. In the preliminary portion and at the commencement of the principal portion, there were sometimes superpositions of the quick movements of period of about 0.4 sec.

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* See the Bulletin, Vol. VI, No. 1, p. 32.

78. *Eruption of Aug. 20th, 1911, at 3. 38. 59 a.m.* Total duration=37 sec. *Longitudinal Component.* [Preliminary tremor.] Duration=5.8 sec. T=0.86 sec., 2a=0.0036 mm. [Principal portion.] Duration=18.3 sec. During the 1st 5.4 sec., the motion consisted chiefly of slow vibrations: T=1.2 sec., 2a=0.019 mm. During the remaining 12.9 sec. of this phase, the motion was composed of nearly uniform quick vibrations of T=0.40 sec., 2a=0.017 mm, mixed with those of period of double length, T=0.80 sec. [End portion.] T=0.72 sec., 2a=0.0025 mm. *Transverse Compcnent.* [Preliminary portion.] Duration=6.1 sec. 2a=0.0062 mm, T=1.0 sec. [Principal portion.] Duration=15.8 sec. T=0.53 sec., 2a=0.019 mm. [End portion.] T=0.65 sec., 2a=0.0018 mm.

79. *Eruption of Aug. 29th, 1911, at 8. 35. 55 p.m.* Total duration=62 sec. In the longitudinal component, recorded by the tromometer, the preliminary portion lasted 2.8 sec., followed by the principal portion which lasted 14 sec. and consisted of 13 nearly regular vibrations of T=1.08 sec., 2a=0.007 mm. In the end portion, the motion consisted of vibrations of T=0.66 sec., mixed with those of T=1.5 sec.

80. *Eruptions of Sept. 9th, 1911, at 11. 49. 21 and at 11. 49. 59. a.m.* These two small outbursts occurred in succession, together lasting 1^{m} 31^{s}. In the longitudinal component of the 1st eruption the preliminary tremor lasted about 2.1 sec., and the principal portion began with 4 slow movements of T=1.6 sec., 2a=0.006 mm; the subsequent portion being made up of the following two series of vibrations:—T=0.87 sec., 2a=0.002 mm; T=1.4 sec., 2a 0.002 mm, mixed with smaller ones of T=0.6 sec. In the 2nd eruption, the principal portion lasted 13.2 sec. and consisted of 14 regular vibrations of T=0.94 sec., 2a=0.003 mm; the subsequent motion being made up of vibrations of T=0.91 sec. mixed with some quick movements. Again, in the earlier and end portions of the two disturbances there were superposition of minute tremors of T=0.35 sec.

81. ***Eruption of Aug. 3rd, 1912, at 7. 51. 03 p.m.*** *Tromometer Diagram: Longitudinal Component.* Total duration=40 sec. The commencement was very gradual and the preliminary tremor lasted 2.0 sec. The principal portion, which lasted 11.3 sec., consisted essentially of 7 slow vibrations of T=1.6 sec., 2a=0.0063 mm; the first being composed of the two displacements of 0.0014 and 0.0052 mm respectively toward, and away from, the crater. The end portion consisted of well-defined vibrations of T=0.65 sec., 2a=0.0026 mm, mixed with traces of the slow vibrations which predominated in the principal portion.

I mention next a few cases of the volcanic manifestations directly observed.

82. ***Eruption of July 1st, 1912, at 5. 33. 40 p.m.*** The present author, staying at the time in the Yuno-taira observatory, perceived the faint rumbling noise, with no simultaneous emission of black smoke from the crater. This was evidently one of those volcanic sounds which occur so frequently, as, for instance, on Dec. 24th, 1911, and each of which accompanies a small outburst throwing out some rock fragments, but causing no special emission of black smoke. According to the tromometer diagram, the longitudinal component lasted 29 sec. and began with the preliminary portion of about 0.6 sec., followed by the principal portion, 4.6 sec. in duration, consisting of 4 vibrations of max. 2a=0.007 mm, T=1.2 sec. In the end portion, which lasted 49 sec., the motion was as follows: T=1.2 sec., 2a=0.002 mm; T=0.9 sec., 2a=0.001 mm. The time of commencement of this extremely small shock, which was of course insensible, was according to the tromometer record, 5. 33. 39 p.m., or 11 seconds earlier than the moment when the sound was perceived at the observatory.

83. ***Eruption of July 2nd, 1912, at 5. 29. 21 a.m.*** (See § 4.) The black smokes were observed from Yuno-taira to appear over the top of the Maikake-yama first at about 5. 29. 50 a.m., or some 30 sec. after the outburst.

In Fig. 60 is reproduced a photographic enlargement of the tromometer diagram (longitudinal component). The total earthquake duration was about 1 min., and the preliminary portion lasted 6 sec., the movements in the principal portion of the two components being as follows:—

Longitudinal Component....Max. 2a=0.0025 mm, T=1.4 sec.
Transverse ,, ...Max. 2a=0.001 ,, , T=1.7 ,,

84. ***Eruption of Aug. 3rd, 1912, at 7. 20. 58 p.m.*** (Fig. 59.) This consisted in an emission of a large quantity of dense gray smokes, whose appearance was first noticed at 7. 23. 10 p.m., by Mr. T. Toyoda at the Yuno-taira observatory. *Tromometer Diagram: Longitudinal Component.* Total duration=21 sec. The commencement of the motion was very gradual and uncertain, the preliminary portion lasting about 3.0 sec. The principal portion, whose duration was 10.0 sec., consisted during the first 4.7 sec. of 3½ slow vibrations of T=1.35 sec., 2a=0.0046 mm, mixed with microtremors of T=0.26 sec.; the remaining part being composed of the smaller movements of T=0.82 sec.. T=0.37 sec. In the end portion, the motion was very small.

85. *Eruption of August 7th, 1912, at 8.12.18 a.m.* The smoke emission of this eruption was witnessed by Mr. T. Toyoda at 8.16 a.m. from the observatory. *Tromometer Diagram*: *Longitudinal Component.* Total duration=25 sec. There was apparently no preliminary tremor, and the motion was active during the first 5.4 sec., the maximum 2a of 0.0028 mm occurring 2.3 sec. after the commencement. The principal portion, in which the T was 0.47 sec., terminated with a conspicuous vibration of 2a=0.002 mm. In the end portion, the motion was very small: T=0.44 sec. This eruption was preceded by a very small one by an interval of 13.8 sec.

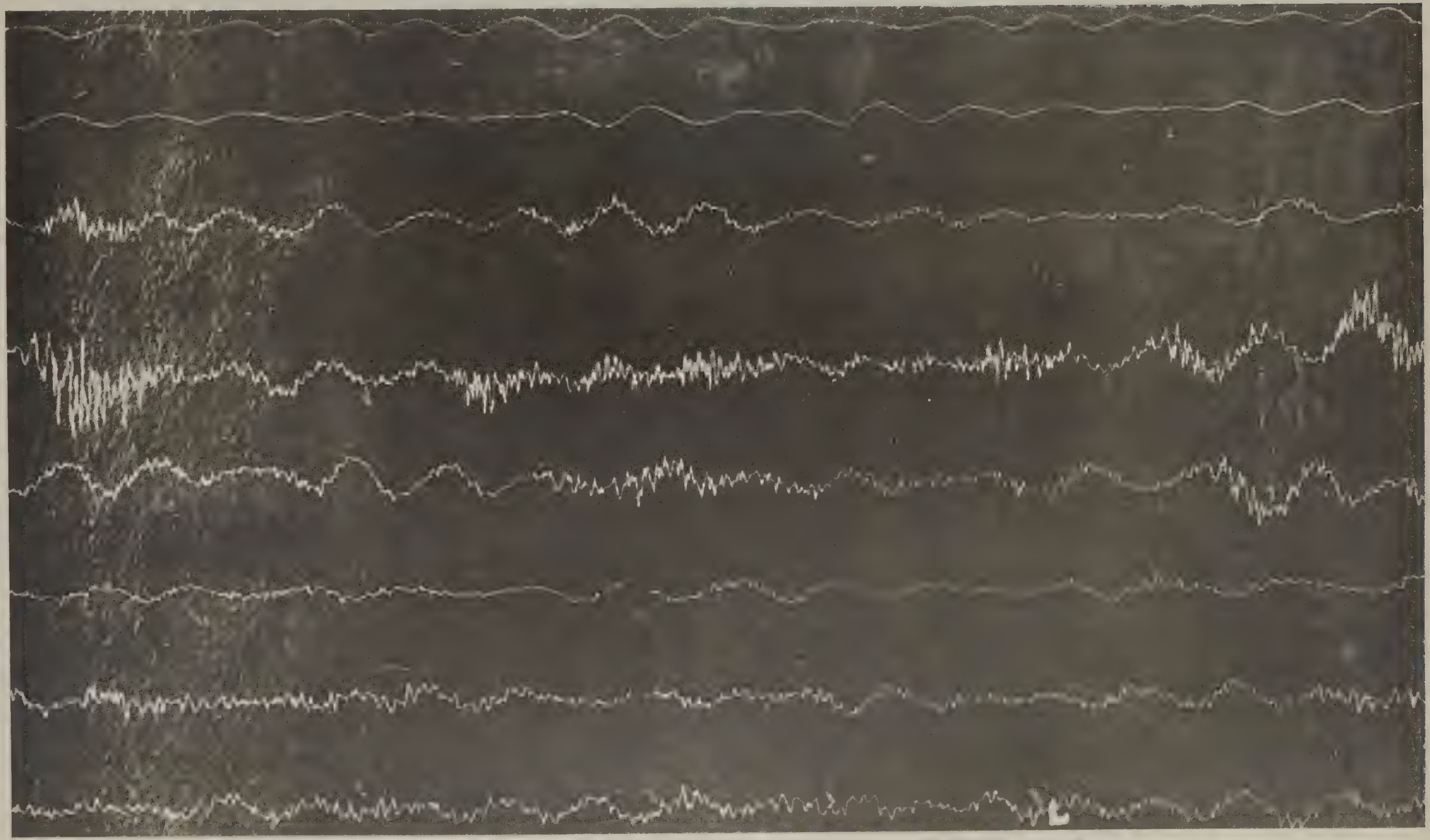
86. *Eruption of Aug. 7th, 1912, at 9.41.03 a.m.* Mr. Toyoda observed the smoke emission of this outburst at 9.49 a.m. from the foot of the Maikake-yama. *Tromometer Diagram*: *Longitudinal Component.* Total duration=55 sec. The commencement was fairly well marked, the preliminary portion (max. 2a=0.0005 mm) lasting 5.1 sec. The principal portion, which lasted 19.8 sec., was as follows:—(i), During the first 9.3 sec., the motion consisted of 6 slow vibrations of T=1.6 sec., 2a=0.002 mm mixed with quick movements of T=0.47 sec., 2a=0.0013 mm; (ii), during the remaining 10.5 sec., the motion became larger and quicker, being composed of the vibrations of T=0.93 sec. (2a=0.0026 mm), T=0.63 sec. (2a=0.0013 mm), mixed with still quicker movements. In the end portion, the vibrations were small: T=0.71 sec. (2a=0.0006 mm).

87. *Eruption of Aug. 22nd, 1912, at 5. 23. 01 a.m.* An emission of black smoke was observed by the present author at 5. 27. 15 a.m. from the observatory. *Tromometer Diagram*: *Longitudinal Component.* Total duration=37 sec. The motion, which began very gradually, was small for the first 9.8 sec. During the next 9.8 sec., it was most active:—(i), in the first 3.9 sec., T=0.33 sec. (2a=0.001 mm), more or less distinctly grouped into movements of double period; (ii), in the remaining 5.8 sec., T=0.65 sec. (2a=0.0012 mm). In the subsequent part, or end portion, the motion was very small.

88. *Eruption of Aug. 23rd, 1912, at 3.13.53 p.m.* This consisted in the emission of a large quantity of dark gray smokes, succeeded by an abundant issue of white vapours; the eruption, accompanied by no sound, being the greatest which occurred in the day-time on the 23rd. As witnessed from the observatory, the smokes first appeared above the Maikake-yama at 3. 14. 13 p.m., or 12 seconds later than the time moment of the earthquake commencement recorded by the tromometer. After this eruption, some feeble rushing sounds were heard at the observatory probably due to an energetic ejection of the steam. *Tromometer Diagram*: *Longitudinal Component.* Total duration=16 sec. The commencement was well defined and the preliminary portion lasted 9.0 sec., during which the movements of T=0.52 sec. were mixed with those of T=0.3 sec., and the amplitude was uniformly small but for the occurrence of a maximum vibration of 2a=0.0006 mm. 2.9 sec. after the commencement. Then followed a single conspicuous slow oscillation of T=0.87 sec., whose two displacements were 0.0032 and 0.0052 mm and were directed respectively away from, and toward to, the crater; the superposed quick movements of T=0.26 sec. also simultaneously attaining the max. 2a of 0.0009 mm. The motion then rapidly decreased, being continued

Fig. 57. **Volcanic Micro-tremors and Eruptive Earthquakes on Oct. 2nd, 1912.**

(Part of the Longitudinal Component Tromometer Diagram at Yuno-taira.)



⟶ Magnification = 810. Time Scale: 1 minute = 144 mm. (Slow regular movements are Pulsatory Oscillations.)

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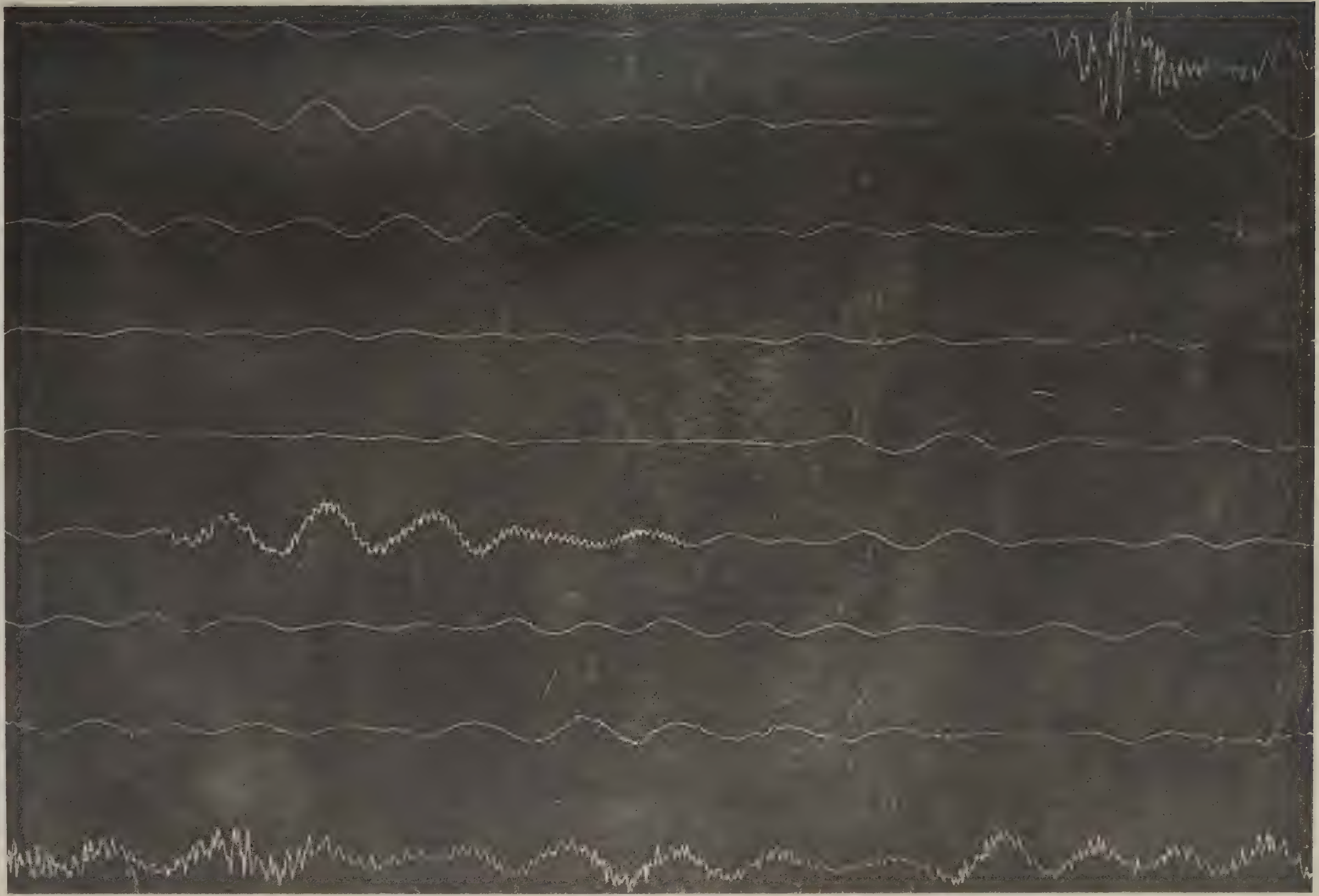
Fig. 58. Volcanic Micro-tremors and Eruptive Earthquakes on Oct. 2nd, 1912.

(Part of the Longitudinal Component Tromometer Diagram at Yuno-taira.)



——→ Magnification = 810. Time Scale: 1 minute = 144 mm. (Slow regular movements are Pulsatory Oscillations.)

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Yuno-taira Seismograms of Smaller Asama-yama Eruptions. [Longitudinal Component.]

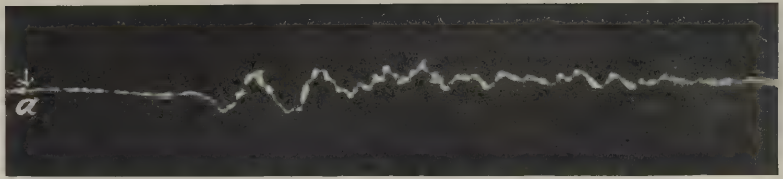

Fig. 59. Aug. 3rd, 1912, at 7.23.23 p.m. (Tromometer Diagram). Magnification = 1220. Time Scale : 1 minute. = 380 mm.

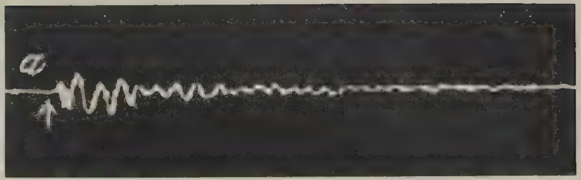

Fig. 60. July 2nd, 1912, at 5.29.21 a.m. (Tromometer Diagram) Magnification = 890. Time Scale : 1 minute = 137 mm.

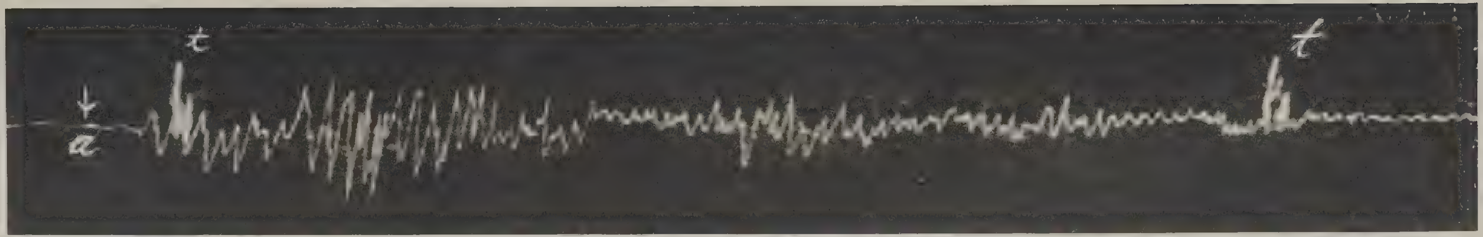

Fig. 61. Aug. 15th, 1911, at 4.42.50 a.m. (Tremor-recorder Diagram.) Magnification = 630. Time Scale : 1 minute = 148 mm.

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for only about 11 sec. after the above-mentioned large movement.

The eruption in question was followed 23.4 sec. after by a very small one of exactly the same character and of the total duration of 14.5 sec. In this second shaking, the time of commencement was 3.14.16 p.m., the motion being small and nearly uniform during the first 9.0 sec. Then there followed a single slow vibration consisting of the two displacements of 0.0007 and 0.0016 mm respectively away from, and toward to, the crater. The subsequent motion was very small.

At 1. 46. 26 p.m., on the same day, there was also a very small earthquake of the same sort; and of the total duration of 30 sec., a single conspicuous vibration (1st motion=0.0006 mm, 2nd motion=0.0009 mm) occurring about 9.5 sec. after the commencement.

CHAPTER IX. REMARKS ON THE SEISMOGRAPHICAL OBSERVATIONS OF THE ASAMA-YAMA ERUPTIONS AT YUNO-TAIRA, ASHINO-TAIRA, AND THE ASAMA PASTURE GROUND.

89. ***Duration of motion of explosive Asama-yama eruptions.*** According to Table XV, the total duration of the longitudinal earthquake motion due to the strong Asama-yama explosive eruptions observed at the three stations of Yuno-taira, Ashino-taira, and the Asama Pasture Ground, was on the average roughly 100 to 150 sec., as follows:—

Yuno-taira	50 to 260 sec.;	mean,	118	sec.
Ashino-taira ..	70 „ 116 „ ;	„ ,	96	„
Asama P. G. ..	110 „ 240 „ ;	„ ,	156	„

The average duration of the principal portion was 25 sec. for Yuno-taira, 21 sec. for Ashino-taira, and 29 sec. for the Asama Pasture Ground. Again, the duration of the specially prominent part varied at Yuno-taira from 8.2 to 19.7 sec., with the average of 15 sec., while the mean duration of the later small stage of the principal portion was at the same observing place about 10 sec. From these latter results for Yuno-taira, whose distance from the crater is only 2.3 km, we may probably infer that the mean durations of (i), the entire principal portion, (ii), the specially active part, (iii), the secondary active part, and (iv), the tail or after shakings, of the explosive process itself at the volcanic focus were not much different respectively from (i) 25 sec., (ii) 15 sec., (iii) 10 sec., and (iv) 90 sec.

TABLE XV. THE TOTAL DURATION, AND THE DURATIONS OF THE PRELIMINARY PORTION AND PRINCIPAL PORTION OF THE EXPLOSIVE ERUPTIONS OF THE ASAMA-YAMA, OBSERVED AT YUNO-TAIRA, ASHINO-TAIRA, AND THE ASAMA PASTURE GROUND.

[Longitudinal Component.]

Explosion.	Prelim. Portion.	Total Duration.	Principal Portion.	Specially strong part.	Later and smaller stage of Princ. Portion.
		Yuno-taira.			
	sec.	sec.	sec.	sec.	sec.
May 16th.	0.26	95	28.2	16.2	12.0
,, 27th.	—	73	29.4	13.8	15.6
,, 29th.	0.16	88	36.1	22.8 (?)	—
June 13th.	—	72	23.2	13.4	9.8
,, 17th.	0.37	115	33.8	—	—
,, 18th.	—	113	24.0	16.4	7.6
,, 20th.	—	94	11.0	—	—
,, 24th.	—	88	12.2	—	—
,, 26th (8 a.m.)	0.47	115	15.7	8.2	7.5
,, 26th (11 p.m.)	0.37	150	28.5	15.3	13.2
July 7th (7 a.m.)	—	78	12.4	—	—
,, 7th (9 p.m.)	0.47	126	14.6	11.3	3.3

Explosion.	Prelim. Portion.	Total Duration.	Principal Portion.	Specially strong part.	Later and smaller stage of Princ. Portion.
Yuno-taira.					
	sec.	sec.	sec.	sec.	sec.
July 8th.	0.29	50	22.2	13.1	9.1
„ 13th.	0.67	138	26.1	15.2	9.9
„ 18th.	0.29	148	25.6	15.2	10.4
„ 19th.	0.48	140	36.4	—	—
Aug. 12th (7 p.m.)	—	120	28.8	19.7	9.1
„ 12th (11 p.m.)	0.42	260	—	—	—
May 5th (1914)	0.55	171	40.0	12.7	27.3
Ashino-taira.					
	sec.	sec.	sec.	sec.	sec
Sept. 21st.	0.49	97	24.3	—	—
Oct. 9th.	0.52	70	—	—	—
„ 15th.	0.50	94	—	—	—
„ 17th.	—	116	21.8	—	—
„ 22nd.	1.0	104	16.2	—	—
Asama Pasture Ground.					
	sec.	sec.	sec.	sec.	sec.
Sept. 21st.	0.61	240	34.9	—	—
Oct. 7th.	—	130	—	—	—
„ 17th.	—	110	34.7 *	33.4	11.3
„ 22nd.	1.6	120	25.3	—	—
Nov. 14th.	1.9	180	20.4	—	—

* Duration of the preliminary and principal portions.

90. ***Duration of preliminary portion in longitudinal component.*** The preliminary portion is in the present cases made up of only one small outward movement, always very small and less than 0.0051 mm, whose average duration was 0.40 sec. for Yuno-taira, 0.63 sec. for Ashino-taira, and 1.4 sec. for the Asama Pasture Ground, the approximate horizontal distances of these three places from the crater centre being 2,300; 4,850; and 6,350 m, respectively. If we assume a linear relation of the form x^{km}= ky sec., between the horizontal radial distance (x) and the duration (y) of the preliminary portion, we get the following values of the constant k:

for Yuno-taira	k=5.8
„ Ashino-taira	k=7.7
„ Asama Pasture Ground	k=4.5

As the average from the results for the three places, we may take k=6, the assumed equation becoming.

$$x^{km}=6\ y\ \text{sec.}, \quad \ldots\ldots\ldots\ldots \quad (1)$$

which relation is of course a very rough one, as the distance x is simply the horizontal distance from the crater centre. It is not clear why the very first, or preliminary, portion is directed outwards. It may be that the motion in question corresponds to the 2nd and large displacement of the "initial vibration" transmitted along the path of the quickest propagation, that corresponding to the 1st displacement of the same vibration being obliterated on account of the smallness of magnitude or some other circumstances.

91. *Initial vibration.* The "initial vibration" (§ 32) forms always a quite prominent feature at the commencement of the longitudinal component principal portion of the *strong* detonative explosions, and its period seems not to vary among the three observing stations of Yuno-taira, Ashino-taira, and the Asama Pasture Ground. It is clearly indicated also in some of the diagrams of the *strong* non-detonative eruptions. In the following table are given, for the "initial vibration" at the different places, the 1st displacement (=a_1) and the 2nd displacement (=a_2); their durations, namely, what may be taken as the 1st half-period and the 2nd half-period; the ratio of a_2/a_1; and the complete period T.

TABLE XVI. ELEMENTS OF THE "INITIAL VIBRATION."

Eruption. (1913)	Range of Motion.			Vibration Period.		
	1st Displ't $=a_1$	2nd displ't $=a_2$	Ratio: $\frac{a_2}{a_1}$	1st half Period.	2nd half Period.	Sum = T.
			Yuno-taira.			
	mm	mm		sec.	sec.	sec.
May 16th.	0.070	0.102	1.46	—	—	1.52
„ 27th.	0.045	0.062	1.38	—	—	1.3
„ 29th.	0.048	0.098	2.05	—	—	2.6
June 13th.	(Small)	(Small)	—	—	—	—
„ 17th.	0.053	0.110	2.08	1.0	1.8	2.8
„ 18th.	(Small)	(Small)	—	—	—	—
„ 20th.	0.010	0.025	2.50	—	—	—
„ 24th.	0.014	0.040	2.85	—	—	1.8
„ 25th.	0.001	0.0034	—	—	—	2.7
„ 26th.(1)	0.021	0.0403	1.92	—	—	1.74
„ „ (2)	0.064	0.093	1.46	—	—	2.3
July 1st.	0.0097	0.043	4.43	—	—	2.0
„ 7th.(3)	0.017	0.037	2.18	0.7	0.78	1.48
„ „ (4)	0.036	0.080	2.22	—	—	1.61
„ 8th.	0.046	0.088	1.91	—	—	1.95
„ 13th.	0.053	0.123	2.32	1.3	1.7	3.0
„ 18th.	0.054	0.116	2.15	—	—	2.2
„ 19th.	0.104	0.127	1.22	—	—	1.75
Aug. 12th.(5)	0.029	0.050	1.73	—	—	1.6
„ „ (6)	0.125	0.217	1.74	1.15	2.0	3.2
„ 15th.	0.010	0.034	3.40	—	—	2.1
May 5th (1914).	0.081	0.143	1.77	—	—	2.16

Eruption. (1913)	Range of Motion.			Vibration Period.		
	1st Displ't $=a_1$	2nd Displ't $=a_2$	Ratio: $\frac{a_2}{a_1}$	1st half Period.	2nd half Period.	Sum = T.
			Ashino-taira.			
	mm	mm		sec.	sec.	sec.
Sept. 21st.	0.030	0.077	2.57	0.97	1.22	2.2
Oct. 9th.	0.0045	0.0175	3.89	1.06	1.21	2.3
„ 15th.	0.009	0.035	3.89	1.05	1.15	2.2
„ 17th.	—	—	—	1.5**	1.2	2.7
„ 22nd.	0.0012	0.0069	5.75	0.9	1.3	2.2
			Asama Pasture Ground.			
Sept. 21st.	0.035	0.043	1.23	0.66	1.12	1.8
Oct. 17th.	0.0062	0.0206	3.32	1.27**	1.26	2.54
„ 22nd.	0.0018	0.0099	5.50	1.44	1.69	3.1
Nov. 14th.	0.038	0.063	1.66	—	—	3.05
„ 20th.	0.005	0.019	3.80	—	—	2.5

(1) At 8.09.40 a.m. (2) At 11.41.59 p.m. (3) At 7.10.32. a.m. (4) At 9.46.53 p m. (5) At 7.45.08 p.m. (6) At 11.20.33 p.m. ** Including the preliminary portion.

According to Table XVI, the 2nd, or outward, displacement (a_2) was, for Yuno-taira, greater than the 1st, or inward, displacement (a_1), in the average ratio of 2.1 : 1. For Ashino-taira and the Asama Pasture Ground, this ratio was greater, being 4.0 or 3.1. The complete period of the "initial vibration" at Yuno-taira was with a few exceptions included between 1.6 and 2.8 sec., the average value being 2.1 sec. At Ashino-taira, it was very uniform, being in the 4 out of the 5 cases, 2.2 or 2.3 sec., with the average of 2.3 sec. Finally, at the Asama Pasture Ground, the period varied between 1.8 and 3.1 sec., with the average of 2.6 sec. The total average, deduced from the observations at the three stations, is 2.2 sec., this being, according to my assumption explained in § 32, the time interval taken by the actual outbursting, or the initial breaking process of the explosion. Again, the approximate average value of the 1st half-period was 0.9 sec., while that of the 2nd half-period was 1.3 sec., which, according to the same assumption are respectively the approximate time interval of the upward push or shock of the explosive force, and that of the quickly following formation of the eruptive aperture by the exploding gases. The slow-period large displacements succeeding the "initial vibration" may also be due to the propagation of the state of the deformation and ultimate rupture of the lava mass at the moment of the explosion.

In the following §§, are given remarks respecting the comparison of the longitudinal and the transverse components, the period of the vibrations (the "initial vibration" excepted), etc.

92. ***Observation at Asama Pasture Ground of strong explosions of* 1913.** The duration of the preliminary portion varied in the transverse component, between 0.62 and 2.5 sec., with the average of 2.1 sec., being 1.1 sec. longer than that in the longitudinal component. The duration of the principal portion varied between 22 and 36 sec., with the averages of 32 and 27 sec. respectively for the longitudinal and the transverse components.

The mean value of the different group periods (Table XVII), deduced from the longitudinal and transverse components, are :—(i) 4.4 sec. ; (ii) 2.46 sec. ; (iii) 1.0 sec. ; (iv) 0.36 sec.

Group.	Average Period.	Max. 2a (Longit. Compt.)	Max. 2a (Transv. Compt.)
i	4.4 sec.	0.035 mm.	— mm.
ii	2.46	0.122	0.106
iii	1.0	0.073	0.073
iv	0.36	0.032	0.028

Of these four groups, the (iii) occurred most frequently, while the (ii) corresponded to the vibrations with the greatest 2a. The time interval between the earthquake commencement and the occurrence of the absolutely maximum 2a was 3.1 to 7.7 sec. in the longitudinal, and 7.8 to 17.5 sec. in the transverse component; the average values in these two directions being respectively 6.1 and 12.5 sec., as follows:—

Explosion.	Longitudinal Component.	Transverse Component.
September 21st.	3.1 sec.	11.1 sec.
October 15th.	—	17.5
October 17th.	7.5	8.9
October 22nd.	7.7	7.8
November 14th.	—	17.2
	Mean, 6.1 sec.	*Mean*, 12.5 sec.

Thus the interval in question was about 5.4 sec. longer in the transverse than in the longitudinal component. The duration of the earlier portion of the earthquake motion free from the mixture of quick vibrations was:—

Explosion.	(1) Longitudinal Component.	(2) Transverse Component.
October 22nd.	4.4 sec.	4.5 sec.
September 21st.	6.9	13.6
October 17th.	10.3	8.8
	Mean, 7.2 sec.	*Mean*, 9.0 sec.

Thus the quick superposed vibrations occurred about 2.0 sec. earlier in the longitudinal than in the transverse component.

TABLE XVII. STRONG EXPLOSIONS IN 1913 OBSERVED AT THE ASAMA PASTURE GROUND: PERIODS.*

(The 2a corresponding to a given period is enclosed in brackets.)

Longitudinal Component.		Transverse Component.	
sec. mm.	mm.	sec.	sec. mm.
4.4 (0.035)	1.47 (0.024)	4.4	1.60 (0.013)
	1.40 (0.011)		1.44 (0.052)
2.65 (0.112)	1.30 (0.007)	2.60 (0.078)	1.30 (0.058)
2.56 (0.122)	1.05	2.60 (0.058)	1.16 (0.048)
2.40 (0.087)	1.02	2.57 (0.035)	1.10 (0.015)
2.20 (0.042)	1.00 (0.007)	2.53 (0.069)	1.10 (0.012)
2.45	0.97 (0.046)	2.48 (0.106)	1.05 (0.009)
	0.96 (0.015)	2.00 (0.010)	1.05 (0.068)
0.36	0.80 (0.073)	**2.46**	1.03 (0.017)
0.25 (0.031)	0.78 (0.031)		1.03 (0.023)
0.27 (0.028)	0.74 (0.012)	0.50 (0.013)	1.03 (0.072)
0.22 (0.032)	0.71 (0.072)	0.48 (0.009)	1.00 (0.030)
0.28	0.70 (0.020)	0.29 (0.028)	0.98 (0.073)
	0.61	**0.42**	0.93 (0.024)
	0.97		0.92 (0.049)
			0.89 (0.022)
			0.83 (0.009)
			0.81 (0.035)
			0.79 (0.066)
			0.70 (0.017)
			1.04

* Exclusive of the "initial vibration." Mean values are printed in gothic figures.

93. ***Strong explosions in 1913 observed at Ashino-taira.*** *Duration.* The duration of the preliminary portion varied in the longitudinal motion between 0.49 and 1.0 sec., and in the transverse between 1.2 and 1.9 sec., with the mean values respectively of 0.63 and 1.6 sec.; it being about 1.0 sec. longer in the latter than in the former component. Again, the duration of the principal portion varied between 15.4 and 24.3 sec., giving for the longitudinal and transverse components the mean values respectively of 20.8 and 18.1 sec.

In the explosions of Sept. 21st and Oct. 22nd, the durations of the specially strong portion in the transverse component were 5.6 and 8.3 sec., giving the mean of 7 sec. Again, in the explosions of Sept. 21st, Oct. 9th and 22nd, the superposition of the quick vibrations in the longitudinal component began respectively 6.1 sec., 5.6 sec., and 4.4 sec. after the commencement, giving the mean interval of 5.4 sec.

Period. As shown in Table XVIII, the mean values of the different group periods averaged from the longitudinal and transverse components are (i) 2.5 sec., (ii) 1.17 sec., and (iii) 0.35 sec. The vibrations of the group (ii) occurred most frequently, while those of the group (i) had the greatest 2a.

Longitudinal Component.		Transverse Component.	
Average T.	Max. 2a.	Average T.	Max. 2a.
2.40 sec.	0.093 mm.	2.50 sec.	0.064 mm.
1.18	0.034	1.15	0.038
0.34	0.020	0.38	—

The period of the *pulsatory oscillations*, or the free vibrations before and after the earthquakes was 3.6 sec. (max. 2a=0.0012 mm) in the longitudinal and 3.8 sec. in the transverse component.

Maximum vibration. The time intervals between the commencement of the earthquake and the occurrence of the maximum vibration in the longitudinal component of the explosions of Oct. 9th and 22nd were 7.4 and 7.0 sec.; while in the transverse components of the explosions of Sept. 21st and Oct. 17th, the intervals were 6.2 and 10.1 sec.

TABLE XVIII. STRONG ASAMA-YAMA EXPLOSIONS IN 1913 OBSERVED AT ASHINO-TAIRA: PERIODS.*

(The 2a corresponding to a given period is enclosed within brackets.)

Longitudinal Component.		Transverse Component.	
sec.	mm.	sec.	mm.
3.2	(0.0663)	2.9	(0.064)
2.6	(0.021)	2.8	(0.0206)
2.43	(0.093)	1.9	(0.0012)
2.1	(0.0042)	**2.5**	
1.9	(0.0275)	1.6	(0.008)
2.4		1.4	
1.47	(0.0024)	1.35	(0.038)
1.45	(0.0048)	1.30	(0.0053)
1.40	(0.011)	1.20	
1.20	(0.0018)	1.12	(0.0011)
1.05		1.01	(0.0206)
1.04	(0.034)	0.90	(0.0028)
0.98		0.87	(0.014)
0.88	(0.0218)	0.73	
1.18		**1.15**	
0.36	(0.020)	0.38	
0.31	(0.0175)		
0.34			

* Exclusive of the "initial vibration." Mean values are printed in gothic figures.

94. ***Strong explosions observed at Yuno-taira.*** The superposition of smaller movements on the "initial" and succeeding slow vibrations in the longitudinal component appeared a few seconds after the earthquake commencement; this interval being, in two of the cases, 2.3 and 3.4 sec. respectively. The time difference between the earthquake commencement and the occurrence of the absolutely maximum motion in the longitudinal component was from 8.0 to 12.3 sec., with the mean value of 10.2 sec., as follows :—

$$\left.\begin{array}{r}8.0\text{ sec.}\\9.2\\9.9\\11.8\\12.3\end{array}\right\}\textit{Mean},\ 10.2\text{ sec.}$$

The maximum 2a of the "quick tremors" was 0.077 mm.

The periods of vibrations (Table XIX) in the principal and end portions of the longitudinal component of the earthquake motion due to the different explosions can more or less distinctly be divided into five groups, of the following mean values :—

(i) T=5.3 sec. (max. 2a=$\overset{\text{mm}}{0.19}$)
(ii) ,,=2.1 ,, (,, =0.048)
(iii) ,,=1.3 ,, (,, =0.130)
(iv) T=0.74 sec. (max. 2a=$\overset{\text{mm}}{0.083}$)
(v) ,,=0.37 ,, (,, =0.053)

TABLE XIX. STRONG EXPLOSIONS IN 1913 AND 1914 OBSERVED AT YUNO-TAIRA : PERIODS.* (LONGITUDINAL COMPONENT.)

(The 2a corresponding to a given period is enclosed within brackets.)

(i)		(ii)		(iii)		sec.	
sec.	mm	sec.	mm	sec.	mm	1.34	mm
6.5	(0.171)	2.3	(0.048)	1.60	(0.0025)	1.36	(0.021)
5.8	(0.140)	2.3		1.60	(0.011)	1.33	(0.022)
4.9	(0.055)	2.2	(0.0065)	1.50	(0.085)	1.30	(0.039)
4.6	(0.134)	1.9		1.47	(0.059)	1.28	(0.041)
4.5	(0.114)	1.85	(0.0058)	1.45		1.24	(0.118)
—	(0.190)	**2.1**		1.41		1.26	
5.3				1.40	(0.0018)	1.20	(0.084)

sec.	mm
1.20	
1.16	
1.14	(0.046)
1.14	(0.017)
1.12	
1.12	(0.031)
1.11	(0.030)
1.10	(0.031)
1.10	(0.023)
1.10	
1.05	(0.105)
1.00	(0.003)
1.3	

(iv)

sec.	mm
0.93	(0.019)
0.89	(0.041)
0.85	(0.009)
0.84	(0.0046)
0.82	(0.012)
0.81	
0.80	(0.062)
0.80	
0.79	
0.78	(0.044)
0.78	(0.0014)
0.77	(0.0027)
0.75	
0.75	(0.023)
0.72	(0.005)
0.71	(0.0162)
0.70	(0.0113)
0.70	
0.70	
0.65	(0.026)
0.65	
0.63	(0.0134)
0.61	
0.60	(0.0036)
0.59	(0.083)
0.58	(0.028)
0.53	(0.0028)
0.73	

(v)

sec.	mm
0.47	(0.0248)
0.45	(0.009)
0.44	(0.028)
0.44	(0.037)
0.44	
0.40	(0.045)
0.40	
0.40	(0.019)
0.40	
0.40	
0.39	
0.38	(0.026)
0.37	(0.0174)
0.36	(0.050)
0.36	(0.0096)
0.36	(0.017)
0.35	(0.021)
0.34	(0.008)
0.33	(0.053)
0.29	(0.0012)
0.27	(0.014)
0.27	(0.029)
0.27	(0.053)
0.26	(0.025)
0.37	

* Exclusive of the "initial vibration." Mean values are printed in gothic figures.

The periods most frequently occurring were (iv) and (v). The magnitudes of the max. 2a's corresponding to the different groups were, excepting (ii), in order of the lengths of period, namely, greatest for (i) and least for (v).

The periods occurring in some of the transverse component diagrams indicated the mean values of 1.4 and 2.6 sec., as follows:

Sec.	mm	
1.52	(2a=0.063)	Mean, 1.4 sec.
1.50		
1.45	(0.004 mm)	
1.44	(0.054 „)	
1.18		

2.9 sec.
2.2 „
} Mean, 2.6 sec.

In the explosions of July 13th and 19th, the maximum vibration in the transverse direction occurred respectively 8.5 and 6.5 sec. after the commencement of the earthquake.

95. *Strong non-explosive eruption of Nov. 20th, 1913, observed at Asama Pasture Ground.* The duration of the preliminary portion was 1.6 sec. longer in the transverse than in the longitudinal component. The duration of the principal portion was also 9.4 sec. longer in the former than in the latter.

The quick vibrations began to appear 5.6 sec. after the earthquake commencement, or 3.6 sec. after the end of the 1st displacement of the "initial vibration." Again, the absolutely maximum movements in the longitudinal and the transverse components occurred respectively 12.3 and 10.9 sec. after the earthquake commencement.

The periods of vibration in the principal and end portions, can be divided in 3 distinct groups, (Table XX), their mean values, averaged from the longitudinal and transverse components, being (i) 2.2 sec.; (ii) 1.1 sec.; and (iii) 0.23 sec. The (ii) period occurred most frequently, while the (i) period corresponded to the greatest range of motion.

TABLE XX. NON-EXPLOSIVE ERUPTION OF NOV. 20TH, 1913, OBSERVED AT THE ASAMA PASTURE GROUND: PERIODS.*

(The 2a corresponding to a given period is enclosed within brackets)

Longitudinal Component.		Transverse Component.	
sec.	mm	(i′)	
3.3	(0.053)	sec.	mm
3.3	(Pendulum period?)	2.20	(0.040)
		1.48	(0.146)
(i)		**1.84**	
2.4	(0.21)		
		(ii′)	
(ii)		1.40	(0.051)
1.20	(0.011)	1.30	(0.012)
1.06	(0.048)	1.07	(0.094)
0.82	(0.062)	1.03	(0.038)
		0.93	(0.100)
1.03			
		1.15	
(iii)			
0.26	(0.032)	(iii′)	
		0.20	
		0.18	(0.011)
		0.19	

* Exclusive of the "initial vibration." Mean values are printed in gothic figures.

96. ***Strong non-explosive eruptions observed at Yunotaira: longitudinal component.*** The duration of the preliminary small portion in the different strong non-explosive eruptions was as follows:—

sec.	mm	sec.	mm
1.5	(max. 2a=0.0027)	47.7	(max. 2a=0.0067)
2.0	(,, 0.034)	56.6	(,, 0.021)
2.3	(,, 0.048)		
3.2	(,, 0.023)		

Mean, 2.3 sec.

In the 1st four cases, the duration in question varied between 1.5 and 3.2 sec., with the average of 2.3 sec.; while in the two remaining cases, it was very long, being about 50 and 60 sec. respectively. Again, the total duration of the principal portion varied between 13.1 sec. and 43.6 sec., with the average of 24.2 sec., while the duration of the specially active part varied between 9.0 and 11.2 sec., with the average of 9.9 sec., as indicated below:—

Principal Portion.
13.1 sec.
13.4 ,,
21.1 ,,
25.0 ,,
28.7 ,,
43.6 ,,
Mean, 24.2 sec.

Specially active part.
9.0 sec.
9.4 ,,
11.2 ,,
Mean, 9.9 sec.

The greatest 2a of the "initial vibration," which was distinctly indicated in three of the cases, was 0.043 mm; the T being 1.08 to 2.1 sec., as follows:—

T=2.1 sec.; 1st motion=0.010 mm, 2nd motion=0.034 mm
2.0 ,, ,, 0.0097 ,, ,, 0.043 ,,
1.08 ,, ,, 0.0052 ,, ,, 0.012 ,,

As will be seen from Table XXI, the periods most frequently occurring in the preliminary portion, the principal portion, and the end portion varied between 1 and 1.5 sec., the average values being respectively 1.21; 1.26; and 1.21 sec. Taking together the three different phases of motion, we obtain the following mean values of period:—(i), 0.32 sec. (max. 2a=0.022 mm); (ii), 0.75 sec. (max. 2a=0.015 mm); (iii), 1.24 sec. (max. 2a=0.048 mm); (iv), 1.85 sec. (max. 2a=0.0067 mm).

TABLE XXI. STRONG NON-EXPLOSIVE ERUPTIONS IN 1913, OBSERVED AT YUNO-TAIRA: PERIODS.* (LONGITUDINAL COMPONENT.)

(The 2a corresponding to a given period is enclosed within brackets.)

Preliminary Portion.	Principal Portion.	End Portion.
sec. mm	sec. mm	sec.
0.23 (0.0013)	0.30 (0.016)	0.23
0.31 (0.0004)	0.23	0.27
0.39	0.45 (0.009)	0.36
0.42	0.24 (0.011)	0.44
0.34	0.27 (0.022)	**0.33**
	3.0	
		mm
0.61 (0.0023)	0.71 (0.0033)	0.58 (0.0015)
0.73	0.80 (0.015)	0.64 (0.004)
	0.90 (0.008)	0.67
0.99 (0.0010)	0.94	0.76 (0.0059)
1.2 (0.0008)	**0.84**	0.77
1.3 (0.0024)		0.82
1.35 (0.0040)	1.00 (0.016)	**0.71**
1.21	1.10 (0.021)	
	1.14 (0.026)	0.97
	1.18 (0.009)	1.04
	1.19 (0.013)	1.08 (0.0037)
	1.20 (0.0027)	1.24 (0.0041)
	1.23 (0.023)	1.25
	1.27 (0.0047)	1.27
	1.34 (0.021)	1.35 (0.0021)
	1.45 (0.023)	1.50
	1.55 (0.031)	**1.21**
	1.54 (0.048)	
	1.26	1.80 (0.0019)
	1.90 (0.0067)	

* Exclusive of the "initial vibration." Mean values are printed in gothic figures.

97. *Small non-explosive eruptions and volcanic tremors on Oct. 2nd, 1912: longitudinal component.* As indicated in the accompanying table, the duration of the principal portion of the non-explosive eruptions varied between 5.7 and 18.6 sec., with the mean value of 10.7 sec.; while that of the preliminary phase was comparatively long and varied between 4.2 and 8.8 sec., with the mean value of 5.8 sec. Thus the preliminary phase lasted on the average about half as long as the principal portion.

Duration of Preliminary Portion.	Duration of Principal Portion.	
4.2 sec.	5.7 sec.	9.4 sec.
4.3	8.0	10.4
4.5	8.1	10.6
4.7	8.4	11.6
5.4	9.0	12.8
5.6	9.0	14.4
5.6	9.0	15.0
6.6		18.6
6.9	*Mean,*	**10.7** sec.
7.0		
8.8		
Mean, **5.8** sec.		

The different periods occurring in the *small eruptions*, which may be grouped into 3 divisions (Table XXII), give the average values practically identical with those in the *volcanic tremors*, as follows:—

Small Eruptions	(i) 1.32 sec.;	(ii) 0.91 sec.;	(iii) 0.46 sec.
Volcanic Tremors....	1.25 ,, ;	0.91 ,, ;	0.41 ,,

In the cases of the small eruptions, the greatest vibrations (max. 2a=0.0283 mm) belonged to the group (i). In the volcanic tremors, the largest vibrations (max. 2a=0.0068 or 0.0067 mm) belonged to the two groups (i) and (ii).

TABLE XXII. SMALL ERUPTIONS AND VOLCANIC TREMORS ON OCT. 2ND, 1912, OBSERVED AT YUNO-TAIRA ; PERIODS. (LONGITUDINAL COMPONENT).

(The 2a corresponding to a given period is enclosed within brackets).

Non-explosive Eruptions (Prel. Tremor, Princ. Portion, Tail).								Volcanic Tremors.			
sec.	mm	sec.	mm	sec.	mm	sec.	mm	sec.	mm	sec.	mm
1.39	(0.0044)	1.10	(0.0068)	0.58	(0.0102)	0.46		1.32	(0.0047)	0.55	(0.0036)
1.37	(0.0283)	1.06		0.58		0.46		1.32		0.50	(0.0047)
1.35	(0.0089)	1.04	(0.0102)	0.58		0.46		1.30	(0.0042)	0.49	(0.0041)
1.32	(0.0037)	1.04		0.57	(0.0040)	0.44	(0.0093)	1.29	(0.0068)	0.49	
1.27	(0.0235)	1.03		0.56	(0.0012)	0.42		1.26	(0.0037)	0.46	(0.0014)
1.27		1.01		0.56		0.41	(0.0068)	1.24	(0.0067)	0.45	(0.0021)
1.27		0.92	(0.0096)	0.55	(0.0125)	0.40	(0.0017)	1.23	(0.0056)	0.38	(0.0009)
1.32 sec.		0.92		0.53	(0.0049)	0.40		1.19	(0.0039)	0 34	(0.0017)
		0.89		0.53		0.40		1.18	(0 0042)	0.32	(0.0009)
		0.89	(0.0009)	0.52	(0.0246)	0.40		1.17	(0.0089)	0.32	(0.0017)
		0.82	(0.0008)	0.52		0.36	(0.0129)	**1.25** sec.		0.29	(0.0025)
		0.72	(0.0008)	0.48	(0.0093)	0.36				0.27	(0.0017)
		0.70	(0.0035)	0.48		0.36		1.00	(0.0027)	**0.41** sec.	
		0.64	(0.0008)	0.47	(0.0164)	0.36		0.97	(0.0034)		
		0.91 sec.		0.47		0.35	(0.0041)	0.96	(0.0033)		
				0.46	(0.0030)	0.33	(0.0081)	0.95	(0.0046)		
						0.31	(0.0078)	0.95			
						0.46 sec.		0.94	(0.0055)		
								0.93	(0.0067)		
								0.92	(0.0037)		
								0.88	(0.0057)		
								0.85	(0.0047)		
								0.84	(0.0060)		
								0.83	(0.0044)		
								0 82	(0.0049)		
								0.91 sec.			

98. ***Small eruptions in 1911-1912 observed at Yuno-taira.*** Table XXIII gives the total duration, and the durations of the preliminary tremor and of the principal portion in the longitudinal and transverse components of the 17 small eruptions observed at

Yuno-taira in the summer months of 1911 and 1912, arranged in order of time length.

TABLE XXIII. SMALL ERUPTIONS IN 1911-1912 observed at Yuno-taira: Duration.

Total Duration.	Duration of Prel. Tremor.		Duration of Princ. Portion.	
	Longitudinal.	Transverse.	Longitudinal.	Transverse.
15 sec.	0.7 sec.	3.4 sec.	4.6 sec.	8.7 sec.
20	1.3	4.2	9.5	8.8
25	2.0	4.8	10.0	12.8
26	3.1	5.3	11.3	14.6
28	3.8	6.1	11.5	15.0
30	3.9	18.2	13.2	15.8
40	4.6		14.0	
43	5.0		14.6	
45	5.1		15.0	
54	5.8		18.3	
60	6.0		18.6	
65	6.6		19.2	
65	9.0		19.8	
68	16.8			
73				
80				
Mean, **46**	**5.3**	**7.0**	**13.8**	**12.6**

According to the above table, the total duration of the disturbances varied mostly from 25 to 70 sec., with the mean value of 46 sec.; while the duration of the principal portion was limited generally between about 9 and 20 sec., with the mean of about 13 sec. The latter may be taken as indicating the average length of time, during which the smokes continued to be emitted vigorously in the small outbursts under consideration. The duration of the

TABLE XXIV. SMALL ERUPTIONS IN 1911 AND 1912 OBSERVED AT YUNO-TAIRA: PERIODS.

(The 2a corresponding to a given period is enclosed within brackets.)

Longitudinal Component.						Transv. Compt.	
(i)		(ii)		(iii)		(i$_1$)	
sec.	mm.	sec.	mm.	sec.	mm.	sec.	mm.
1.7	(0.001)	0.95	(0.015)	0.52		1.4	(0.0033)
1.6	(0.006)	0.94	(0.002)	0.47	(0.0028)	1.25	(0.014)
1.6		0.93	(0.0026)	0.47		1.2	
1.6		0.92		0.44		**1.28**	
1.5	(0.013)	0.91		0.43			
1.5		0.90	(0.018)	0.40	(0.017)	(ii$_1$)	mm.
1.4	(0.0025)	0.90		0.40		0.91	(0.0036)
1.4		0.87	(0.0052)	0.40		0.88	(0.005)
1.4		0.87		0.38		0.80	(0.021)
1.35	(0.0046)	0.86	(0.0036)	0.37		0.79	(0.018)
1.32	(0.022)	0.82	(0.0023)	0.35		0.78	(0.0035)
1.20	(0.019)	0.82		0.33		0.77	(0.030)
1.20		0.80	(0.013)	0.30		0.72	(0.014)
1.20		0.80		0.26		0.72	
1.10	(0.023)	0.80		**0.39**		0.67	(0.004)
1.08		0.78	(0.0031)			0.65	(0.0018)
1.38		0.76	(0.0036)			0.58	
		0.75	(0.031)			0.54	
		0.74	(0.007)			0.53	(0.017)
		0.74				**0.72**	
		0.72	(0.0025)				
		0.71					
		0.66					
		0.65	(0.0026)				
		0.65					
		0.63	(0.0013)				
		0.60					
		0.80					

preliminary tremor, which is in the present instances to be regarded as mainly denoting the interval of the premonitary phase of the eruption, varied within wide limits, namely, from 0.7 sec. up to 18.2 sec.; the discrepancy of 1.7 sec. between the average values in the longitudinal and the transverse directions, namely, 5.3 and 7.0 sec., being probably due to the difference in the propagation velocity of the two component waves.

The periods of vibrations occurring in the different cases were, arranged according to descending order of magnitude, as in Table XXIV; the mean values of the different groups being, for the longitudinal component, 1.38 sec. (max. 2a=0.023 mm), 0.80 sec. (max. 2a=0.031 mm), 0.39 sec. (max. 2a=0.017 mm), and, for the transverse component, 1.28 sec. (max. 2a=0.014 mm), 0.72 sec. (max. 2a=0.030 mm).

99. ***Average vibration periods at different places.*** In Table XXV are collected the average values of the different group periods occurring in the seismograms of the various Asama-yama eruptions observed at Yuno-taira, the Asama Pasture Ground, and Ashino-taira; those in the records of the ordinary or distant earthquakes (Chapter XI) obtained at the two former places being also given, for the sake of reference.

TABLE XXV. AVERAGE VIBRATION PERIODS AT THE DIFFERENT OBSERVING PLACES. (L)....LONGITUDINAL. (T)....TRANSVERSE.

Periods of frequent occurrence are printed in thick letters, while those corresponding to large 2a are indicated with *asterisks*.

Eruption.	Observing Place.		i	ii	iii	iv	v	vi
			sec.	sec.	sec.	sec.	sec.	sec.
Strong Explosion.	Yuno-taira	L	—	5.3*	2.1	**1.3***	**0.74***	0.37
		T	—	—	2.5 ?	**1.4**	—	—
	Asama Pasture Ground	L	—	4.4	**2.45***	—	**0.97***	0.35
		T	—	4.4	**2.46***	—	**1.04***	
	Ashino-taira	L	—	—	**2.4***	**1.18**	—	0.35
		T	—	—	**2.5***	**1.15**	—	
Strong Non-Explosive Eruption.	Yuno-taira	L	—	—	1.85	**1.23***	**0.74**	0.33
		T						
	Asama Pasture Ground	L	—	—	2.4*	**1.03**	—	0.23
		T	—	—	2.02*	**1.15**	—	
Small Eruptions (1911—1912).	Yuno-taira	L	—	—	—	1.38	**0.80***	0.39
		T	—	—	—	1.28	**0.72***	—
Small Eruptions and Volc. Tremors. (Oct. 2nd, 1912.)	*Do.*	L	—	—	—	**1.32***	**0.91**	**0.45**
		T	—	—	—	**1.25***	**0.91**	0.51
Ordinary Earthquakes.	Yuno-taira.	L	26.4	6.0	2.2	—	0.95	0.38
	Asama P. G.	L	—	5.4	—	—	0.76	0.28

According to Table XXV, the vibrations composing the earthquake movements caused by the eruptions of the Asama-yama, whether explosive or non-explosive, seem to be essentially of equal periods at the different observing places; there being no material difference in this respect between the longitudinal and the transverse components. The periods can evidently be classified into the five groups, ii, iii, iv, v, and vi, whose general average values are as follows:—

(ii) 4.9 sec.
(iii) 2.3 ,,
(iv) 1.23 ,,
(v) 0.85 sec.
(vi) 0.37 ,,

The period most frequently occurring are (v) and (iv), and then (iii), while all these three groups correspond to the large values of 2a. Further, it seems probable from the table, that the different periods occurring in the cases of the eruptions, and others much longer, are to be found in the diagrams of ordinary, or non-volcanic, earthquakes observed on, or at the base of, the Asama-yama. The various periods considered above must, therefore, be assumed to be characteristic of the mass of the volcano, including the region surrounding it. The period (ii) is identical in nature with the pulsatory oscillations, while (iii) is evidently identical with the period of the "initial vibration" (§ 91). Thus the duration of the eruptive process at the moment of the outburst seems to be regulated by the proper oscillations of the mountain system itself. The quick vibrations of period (vi) of about $\frac{1}{3}$ sec., which occurred some interval after the "initial vibration," may possibly be the surface waves caused by the latter and the succeeding large movements attending the actual explosion. The time interval between the first appearance of those minute movements and the earthquake commencement seems to be different for the three places of observation. (See Chapter XIV.)

As may be noticed from Table XXV, there is no fundamental difference in the values of the various periods between the longitudinal and the transverse components. In a few cases, however, the period of the vibrations occurring at the commencement of the transverse component was half of that in the corresponding epoch of the longitudinal, a property which is often found to be the case of the movements in the two directions in question.

100. ***Direction of preliminary portion and "initial vibration."*** The average durations of the preliminary portion of the small eruptions and volcanic micro-tremors on Oct. 2nd, 1912, and of the other small eruptions considered in Chapter VIII, were respectively 5.3 and 5.8 sec., those of the strong non-explosive eruptions being sometimes much longer. The preliminary portion in these cases are quite different in nature from the ordinary preliminary tremor. The preliminary portion, or the exceedingly small outward displacement at the very commencement of the explosive eruptions, seem to be almost entirely longitudinal in nature. Thus, in the three explosions of July 7th and 13th, 1913, and of May 5th, 1914, observed at Yuno-taira, the directions of the motion in question were respectively N70° W, S88° W, and S85° W, giving the mean of about N85° W, while the crater is approximately towards the N20° E from the observatory. Again, in each of the eruptions of July 7th and Nov. 20th, 1913, observed at Yuno-taira, the direction of the preliminary portion was nearly longitudinal.

The direction of the 1st displacement of the "initial vibration" was also accurately or very nearly longitudinal in the cases of the 4 explosions observed at the Asama Pasture Ground. In the 3 cases of the explosions of July 7th and 19th, 1913, and of May 5th, 1914, the direction in question were respectively toward N63° E, N70° E, and N86° E, giving the mean of N73° E, or the direction of the crater.

101. *Small slow regular vibrations on Aug. 12th, 1913.* (Fig. 48.) For 13½ min. between $1^{h}\ 26\frac{2}{3}^{m}$ and $1^{h}\ 40\frac{1}{4}^{m}$ p.m., on Aug. 12th, 1913, the tromometer diagrams indicated an unbroken series of perfectly regular small vibrations, which were not due to a direct explosion or earthquake shock, but must have been the result of a gradual accumulation of some internal volcanic tension composing a forerunner of the subsequent strong explosions. According to this assumption the movements under consideration were nothing else than one of the types of the natural vibrations of the top portion of the Asama-yama, or the surface rocky material resting on the lava reservoir, which was thrown into a state of free oscillations by the incessant or frequent applications of impulsive pressure from within, just in the same manner as a bridge truss of long span is caused to vibrate with a gradually increasing amplitude by the running of a man or the slow passage of a train over it.

Tromometer Diagram : Longitudinal Component. The motion, which was at first small, with the average period of 1.24 sec., was gradually increased in the course of about 130 sec. to 2a=0.0028 mm, with the average period of 1.34 sec. ; thence decreasing to a minimum in about 32 sec. For the next 2¼ min. the motion presented a series of smaller vibration groups at an average interval of about 29 sec., the mean value of the average periods measured in the maximum and minimum parts being respectively 1.17 and 1.16 sec. as follows.

Maximum Part :—		Minimum Part :—	
T=1.16 sec.	(max. 2a=$\overset{\text{mm}}{0.0018}$)	T=1.20 sec.	(max. 2a=$\overset{\text{mm}}{0.0014}$)
1.15 ,,	(,, 0.0025)	1.13 ,,	(,, 0.0011)
1.27 ,,	(,, 0.0018)	1.17 ,,	(,, 0.0011)
1.08 ,,	(,, 0.0018)	1.13 ,,	(,, 0.0007)

In the later portion, the elements of the well defined motion was as follows : T=1.13 sec., 2a=0.0015 mm.

In the tremor-recorder diagram (magnification=100), the motion was only slightly indicated in the longitudinal direction, but distinctly in the transverse direction. The average period in the principal part of the latter component was 1.27 sec. It may be remarked that the period of the regular vibration in question was the same as that of the group (iv) in § 99.

CHAPTER X. NON-ERUPTIVE VOLCANIC EARTHQUAKES OBSERVED AT YUNO-TAIRA, ASHINO-TAIRA, AND THE ASAMA PASTURE GROUND.

102. I describe below, just by way of examples, only a few typical cases of the Asama-yama volcanic earthquakes which were accompanied by no eruption; the illustrative diagrams being given in Figs. 70 and 71.

103. ***Examples of shocks of short duration observed at Yuno-taira.*** In this § I describe a few cases of the volcanic shocks, whose principal portion was of a very short duration.

Earthquake of Sept. 13th, 1911; *at* 8. 43. 09 *p.m.*: *Longitudinal Component.* (Fig. 71.) (Duration=10 sec.) The commencement of the earthquake was perfectly abrupt, the 1st displacement being 0.055 mm directed toward the crater, followed by the maximum movement of 2a=0.12 mm directed away from it. Thereafter the motion rapidly decreased, the duration of the earthquake proper being only 2.6 sec. The end portion, about 7 sec. in duration, consisted of minute movements, whose 2a was less than 0.001 mm. This earthquake was preceded by a very small shock, which occurred at 8. 42. 30 p.m., and whose initial and maximum displacement was about 0.001 mm.

Earthquake of Sept. 26th, 1911, *at* 3. 24. 46 *and* 3. 24. 56 *a.m.*: *Longitudinal Component.* These two shocks together formed a continuous disturbance, whose principal portion lasted 5.1 sec., the max. 2a's being respectively 0.012 and 0.011 mm. The end portion was very small and lasted about 5 sec. The 1st earthquake was preceded 9 sec. earlier by a very slight shock of total duration=3 sec.

Earthquakes of Sept. 26th, 1911, *at* 3. 26. 16 *and* 3. 26. 37

a.m.: *Longitudinal Component.* The 1st earthquake, which was not sensible and lasted 21 sec., began with an initial displacement of 0.002 mm. The maximum 2a of 0.03 mm took place at the commencement of the principal portion, whose duration was 2.8 sec. The end portion, about 18 sec. in duration, seemed to be composed during the first 3.0 sec. of two extremely small shocks occurring in quick succession. The principal portion of the 2nd earthquake, which was much larger and sensible, lasted 6.5 sec. and began abruptly, the 3rd vibration being the greatest, 2a= 0.09 mm. In the 1st 16.6 sec. of the end portion, the vibrations, which rapidly decreased, continued quick in period: T=0.35 sec. During the remaining 50 sec., the quick vibrations almost disappeared, and the motion consisted principally of slow movements of T=1.4 sec. and of those of T=0.78 sec. Total duration of the 2nd earthquake=78 sec.

Earthquakes of Oct. 5th, 1911. The *earthquake at* 2. 40. 46 *a.m.* This was the largest of the group of the shocks on Oct. 5th and was sensible at Yuno-taira, commencing with the max. vibration, 0.26 and 0.19 mm respectively in the longitudinal and the transverse directions. The motion quickly decreased and was brought to end respectively in 30 and 20 sec. in the two directions. This disturbance was preceded by a small sensible shock, of max. 2a= 0.042 and 0.046 mm respectively in the longitudinal and the transverse components. The *earthquake at* 2. 43. 00 *a.m.* was the next largest on the same day, with the max. 2a=0.10 and 0.11 mm in the long. and the trans. directions. It was preceded 5.4 sec. before, also by a small sensible shock of max. 2a of 0.11 and 0.07 mm in the two components. In the small sensible *earthquake at* 4. 48. 16 *a.m.*, the initial displacement was 0.009 mm directed toward S86° E, the max. 2a being about 0.05 mm in each component. It seems probable that the origin of this disturbance was situated some distance to the S. of the crater.

Earthquake of Sept. 21st, 1912, *at* 3.46.34 *a.m.*: *Longitudinal Component.* Total duration=42 sec. [Preliminary and principal portion: duration=4.2 sec.] After a very brief preliminary tremor, whose 1st displacement was directed toward the crater, the motion at once reached the max. 2a of 0.15 mm, being most active for the 1st 2.0 sec. For the next 2.2 sec., the motion was much smaller (max. 2a=0.041 mm), but still active. [End portion.] The motion was very small.

The period of the small *pulsatory oscillations*, which prevailed at the time of the earthquake, was about 5.0 sec.

104. *Examples of shocks of larger magnitude observed at Yuno-taira.* Two earthquakes of larger type are mentioned here.

Earthquake of July 24th, 1911, *at* 5. 56. 44 *a.m.* This was sensible at Yuno-taira and felt *moderately* at Wakasare, the village of Omai and the town of Naganohara, in the province of Kotsuke, and *slightly* at the towns of Ueda and Komoro, in the province of Shinano, while it was registered as an unfelt disturbance by the ordinary seismographs at the meteorological observatories of Nagano, Maebashi, Osaka, and Tokyo.

Tremor-recorder Diagram. Total duration=about 1 min. The commencement was perfectly sharp, and the first motion was 0.40 mm directed toward N 80.5° E, this probably pointing away from the origin of disturbance. For the 35.5 sec. following the above-mentioned initial displacement, the record consisted of rapid vibrations mixed with a series of the quickly decreasing pendulum movements, which were greatest at first and whose elements were as follows:—

Longitudinal Component: Max. 2a=1.00 mm, T=3.6 sec.;
Transverse " : Max. 2a=0.76 " , T=4.1 " ;

In the succeeding portion, the motion consisted mainly of the gradually decreasing quick vibrations of T=1.0 sec., whose max. 2a was 0.075 mm in each component. Before the earthquake was brought to the end, there began a number of the after-shocks, whose times of occurrence were 5.58.02 ; 5.58.52 ; 6.00.54 ; 6.01.41 ; 6.02.05 a.m.

At Nagano, the principal earthquake was registered as an unfelt disturbance of a total duration of 3^m51^s; preliminary tremor duration=5.7 sec.; max 2a=0.10 mm, T=3.2 sec.

Earthquake of July 24th, 1911; *at* 9.11.49 *a.m.* This was sensible at Yuno-taira and was felt as a *moderate* shock at the towns of Ueda, Matsushiro, and Komoro, in the province of Shinano, and at Wakasare and the village of Omae, in the province of Kotsuke, while it was recorded as an unfelt disturbance by the ordinary seismographs at the meteorological observatories of Nagano, Maebashi, Kofu, Kanazawa, Nagoya, Osaka, and Tokyo. The earthquake, whose area of sensible motion was roughly an ellipse of the EW major diameter some 50 km in length, originated probably from a centre near to that of, but was appreciably larger in magnitude than, the preceding shock.

Tremor-recorder Diagram. Total duration=about $2^m 30^s$. In the longitudinal component, the earthquake indicated apparently no preliminary tremor, but began with a sudden large displacement of about 0.45 mm toward ENE, followed by the counter motion of 1.24 mm, after which the pointer went out of the smoked paper. In the transverse component, the initial displacement was 0.048 mm, directed toward SSE; giving the resultant initial displacement of about 0.78 mm toward N72°E, i.e., directed almost exactly toward the crater. During the next 13.4 sec., the motion was most active and consisted of the vibrations of T=1.9 sec., max. 2a=1.45 mm, mixed with the much quicker movements. During the next 39.1 sec., there predominated the latter sort of motion, of T=0.78 sec., 2a=0.24 mm. So far may be taken as the principal portion. During the 1st 42.4 sec. of the end portion, the principal period was T=1.3 sec., (2a=0.07 mm). Thereafter the motion became very small: T=2.4 sec., 2a=0.015 mm.

At the meteorological observatory of Nagano, this earthquake was registered as an unfelt disturbance of the following elements: Duration of preliminary tremor=5.8 sec.; total duration=7^m10^s; max. 2a=0.28 mm, T=3.4 sec. The duration of the preliminary tremor corresponds to the radial distance of 5.6×7.48 km=42 km, which is not sensibly different from the actual distance between Nagano and the Asama-yama crater.

After-shocks. The foregoing disturbance was followed at Yunotaira by two small sensible shocks, whose times of occurrence were respectively 9.15.39 and 9.16.19 a.m. In the 1st of these, the initial displacement was 0.017 mm directed toward S72°E, the preliminary tremor lasting 0.7 sec. In the 2nd shock, the initial displacement was 0.012 mm directed toward S71°E, the preliminary tremor lasting 1.1 sec. It thus appears that these after-shocks originated from points different from the centre of the principal earthquake, probably from the SE neighbourhood of the crater.

105. ***Examples of observation at Ashino-taira and Asama Pasture Ground.*** *Earthquakes of Oct. 12th,* 1913, *at* 8.25.52 *a.m.* This was evidently a local shock and was perceived as a slight shaking at Ashino-taira, but not felt at Komoro and the Asama Pasture Ground. The origin of the disturbance seems to have been situated about 4 km to the west of the crater, namely, some 3 km to the N of Ashino-taira and about 9 km to the WSW of the Asama Pasture Ground.

Tremor-recorder diagram at Ashino-taira. Total duration=92 sec. [ENE-WSW Component.] The preliminary motion lasted only about 0.6 sec.: max. 2a=0.002 mm. Principal portion lasted 16.4 sec. and the motion, which consisted entirely of quick vibrations of T=0.42 sec., max. 2a=0.058 mm, was most active during the 1st 5.6 sec. A maximum group of 2a=0.02 mm, which occurred 18.2 sec. after the commencement of the earthquake, was probably due to a 2nd small shock. In the end portion, the vibrations of T=1.8 sec., max. 2a=0.0047 mm, were mixed with the quick movements of max. 2a=0.0041 mm. [SSE-NNW Component.] The preliminary portion consisted of a single small NNW'ward displacement of 0.0008 mm and of 0.3 sec. in duration. The principal portion, (including the 2nd shock of max. 2a=0.0089 mm), lasted 15.8 sec., and was most active during the 1st 5.4 sec., consisting entirely of the quick vibrations of T=0.38 sec., max. 2a=0.073 mm. In the end portions, small regular vibrations of T=0.45 sec., max. 2a=0.0007 mm, were mixed with those of T=1.1 sec.

Tremor-recorder diagram at Asama Pasture Ground. Total duration=25 sec. [ENE-WSW Component.] The preliminary tremor lasted 1.2 sec.: max. 2a=0.009 mm. During the next 20.5 sec., the motion was most active, and consisted of quick vibrations of T=0.32 sec., max. 2a=0.048 mm, mixed with slower ones of T=0.71 sec. During the next 21.8 sec., the quick movements gradually disappeared, the motion being composed chiefly of the vibrations of T=0.85 sec., whose 2a gradually decreased from 0.025 mm to 0.010 mm. In the subsequent portion the vibrations were small but regular: T=0.79 sec., max. 2a=0.003 mm. During the principal portion there were traces of slow oscillations of T=4.6 sec. [SSE-NNW Component.] During the preliminary tremor, which lasted 1.2 sec., the motion was practically *nil.* For the next 22.0 sec., the motion was most active and consisted of quick vibrations of T=0.30 sec., max. 2a=0.044 mm, mixed with well defined movements of T=0.78 sec., and grouped into slow oscillations of T=5.4 sec. During the next 23.7 sec., the vibrations were regular: T=0.92 sec., max. 2a=0.016 mm. The subsequent motion was very small.

106. ***Tremors caused by the falling down of rock fragments.*** At half past 8 on the morning of Sept. 12th, 1911, a large quantity of rock fragments rolled down the inner slope of the Kurofu-yama at a place called Tomi-no Kuchi ("mouth of winnowing machine" so named from the resemblance of its form), at an elevation of about 270 m above, and at a direct distance of about 550 m to the WNW of, the Yuno-taira observatory. The motion, which lasted 60.0 sec. and reached the maximum extent of 2a=0.074 mm at 33.3 sec. from the commencement, consisted of quick vibrations of about 0.37 sec. in period grouped into a number of maxima, due probably to a succession of the disturbances at the origin. There was a sort of exceedingly small preliminary tremors for the 21½ sec. preceding the main disturbance, but the termination of the latter was quite abrupt, indicating practically no after-effect.

From examples like these it can be inferred that on the occasion of a strong explosion of the Asama-yama, a lava fragment of moderate dimensions projected with a considerable force from the crater and falling in the vicinity, say, within 200 metres, of the observatory, would leave records of no small magnitude on the smoked paper of the tromometers.

CHAPTER XI. ORDINARY EARTHQUAKES OBSERVED AT YUNO-TAIRA, ASHINO-TAIRA, AND ASAMA PASTURE GROUND.

107. In the next three §§ I give examples of the observations at the Asama-yama stations of ordinary earthquakes which originated in the vicinity of the volcano and those which originated at distances of over 100 km from it.

108. ***Earthquakes of near origin observed at Yuno-taira.*** *Earthquake of Sept. 20th,* 1912, *at* 11. 40. 04 *p.m.* The origin was in the neighbourhood of the town of Ueda.

Longitudinal Component: total duration$=2^{m}40^{s}$. The preliminary tremor lasted 3.5 sec. and consisted of 1½ vibrations of $T=2.4$ sec., $2a=0.0099$ mm, the 1st and outward displacement being 0.0034 mm. [Principal portion: duration$=47.8$ sec.] During the 1st 5.2 sec., the motion was comparatively small and composed of two oscillations of $T=2.6$ sec., $2a=0.031$ mm, mixed with small vibrations of $T=0.38$ sec. For the next 11.3 sec., the motion was active, consisting of quick vibrations of $T=0.35$ sec., max. $2a=0.025$ mm, mixed with the slower ones of $T=0.87$ sec. During the remaining 31.5 sec., the motion consisted chiefly of the vibrations of $T=2.2$ sec., mixed with those of $T=0.91$ sec., the largest (absolute maximum) of which was $2a=0.065$ mm and occurred at the commencement of this phase. During the principal portion there were distinct traces of slow oscillations of $T=4.4$ sec. [End portion.] During the 1st 23.1 sec., the vibrations of $T=2.3$ sec. were mixed with the quicker ones of $T=0.93$ sec., $2a=0.011$ mm. Thereafter the motion became much smaller, being composed at first of the vibrations of $T=2.9$ sec., max. $2a=0.0054$ mm, mixed with quicker ones of $T=0.85$ sec. Toward the end, the period became about 1.5 sec.

Earthquake of Oct. 5th, 1911; *at* 11.51.22 *p.m.* The earthquake was felt *moderately* at the village of Omae (in Kozuke), and the towns of Ueda and Suzaka (in Shinano), respectively 12 km to the N, 24 km to the W, and 34 km to the N35°W, of the Asama-yama crater. It was sensible at Nagano, and recorded as an unfelt shaking by the ordinary seismographs at the meteorological observatories of Mito, Mount Tsukuba, and Matsumoto. According to the tremor-recorder diagram obtained at Yuno-taira, the first and the counter displacements were respectively 0.029 mm toward S87°E and 0.17 mm toward N75°W, giving the average direction of S81°E and N81°W. The earthquake origin was, judging from the area of disturbance, situated in the latter azimuth, near the town of Ueda.

In the tromometer record (ENE and WSW component), the motion, whose two introductory displacements were 0.028 and 0.150 mm toward ENE and WSW respectively, was most active for the first 13.4 sec., with the average T of 0.96 sec.; the absolute max. 2a of 0.18 mm occurring 3.6 sec. after the commencement. During the next 13.1 sec., the motion was smaller but still active: max. 2a=0.054 mm, T=0.93 sec. During the next 19.2 sec., the vibrations of T=1.9 sec. (2a=0.035 mm) were mixed with those of T=1.07 sec. So far may be taken as the preliminary tremor and the principal portion. During the first 40.5 sec. of the end portion, the vibrations of T=1.4 sec. (2a=0.013 mm) were mixed with those of slower ones. In the subsequent portion the motion was very small: 2a=0.003 mm, T=2.9 sec. As will be seen from the above account, the motion was large from the outset. The initial portion preceding the absolute maximum may, however, be taken as the preliminary tremor, whose duration was then 3.6 sec., corresponding to the radial distance of about 27 km. The approximate position of the earthquake origin thus determined is about 4 km to the NW of Ueda, at $\varphi = 36°26'$N, $\lambda = 138°13'$E.

Observation in Tokyo. According to the 120-times EW-component tromometer diagram, the time of occurrence was 11.52.00 p.m., the duration of the preliminary tremor being 22.5 sec. During the 1st 17.9 sec. of the principal portion, the motion was comparatively small. During the next 50.4 sec., it was most active and consisted of 8½ vibrations of T=5.9 sec., the 3rd displacement being the maximum, 2a=0.11 mm. Total duration=6 min.

Observation at Nagano. Time of occurrence=11.51.55 p.m.: duration of preliminary tremor=3.3 sec.; max. 2a=0.47 mm; total duration=4^{m}.

Earthquake of Oct. 6th, 1911; *at* 8.50.35 *a.m.* This earthquake, which was a little larger than the preceding, was felt *moderately* at Omae, Ueda, and Shiozaki (Sarashina county, Shinano), which last is 41 km to the N 68°W from the Asama-yama crater. It was sensible at Nagano, and recorded as an unfelt shock by ordinary seismographs at the meteorological observatories of Tokyo, Kumagai, Matsumoto, Kofu, Nagoya, and Osaka. According to the tremor-recorder diagram obtained at the Yuno-taira observatory, the earthquake began quite sharply with a displacement of 0.04 mm directed toward N89°E, the counter motion being 0.24 mm directed toward N67°W. These give the average direction of S78°E and N78°W, the earthquake origin being probably situated in the latter azimuth, and quite near to that of the shock on the 5th.

In the tromometer diagram (ENE-WSW component), the motion, whose two introductory displacements were 0.044 and 0.21 mm toward ENE and WSW respectively, was most active for the first 14.5 sec., with the average T of 1.1 sec.; the absolutely max. 2a of 0.32 mm occurring 5.4 sec. after the commencement. There were also vibrations of T=2.7 sec. During the next 13.9 sec., the motion consisted of well defined quick vibrations of T=1.0 sec. (2a=0.10 mm). During the next 19.7 sec., the motion was smaller and consisted of the vibrations of T=1.0 sec. (2a=0.061 mm), mixed with those of T=2.5 sec. Thereafter the motion rapidly decreased.

Observation in Tokyo. According to the 120-times EW-component tromometer record, the time of commencement was 8.50.46 a.m., the duration of the preliminary tremor being about 21.1 sec. During the 1st 20.0 sec. of the principal portion, the motion was comparatively small. For the next 54.0 sec., it was most active, and consisted of 8½ vibrations of T=6.4 sec., the 3rd displacement being the maximum, 2a=0.2 mm. Total duration=6 min.

Observation at Nagano. Time of occurrence=8.50.24 a.m.; duration of preliminary tremor=4.6 sec.; max. 2a=0.72 mm; total duration=5^m12^s.

Earthquake of Aug. 13*th*, 1913, *at* 4. 27. 20 *a.m.* The earthquake originated from the vicinity of the city of Matsumoto. Longit. Compt.: total duration=2^m 16^s. The preliminary tremor, which was clearly indicated, lasted 6.5 sec., and consisted of small vibrations of T=0.27 sec., mixed with those of T=0.55 sec., 2a=0.0019 mm. [Principal portion: duration=10.4 sec.] During the 1st 0.6 sec., the motion was small: max. 2a=0.0046 mm. For the next 2.5 sec., the vibrations were quick and most active: max. 2a=0.028 mm. During the remaining 7.3 sec., the vibrations gradually decreased to 2a=0.0073 mm. [End portion.] The motion was composed of vibrations of T=0.84 sec., max. 2a=0.0033 mm, mixed with the quicker ones of T=0.33 sec.

109. *Examples of distant eqkes observed at Yuno-taira.*

Earthquake of July 9th, 1912, at 5.31 *p.m.* The earthquake originated off the coast of Kii. Longitudinal Compt.; total duration$=8^m\ 8^s$. The preliminary tremor lasted 46.3 sec. and consisted of vibrations of T=1.5 sec., max. 2a=0.013 mm, mixed with others of longer and shorter periods. [Principal portion: duration$=3^m\ 7^s$.] During the 1st 59.4 sec., the vibrations of T=5.5 sec., max. 2a=0.036 mm, were mixed with those of T=2 sec. and others, the period of the slow superposed oscillations being about 26.4 sec. During the remaining $2^m\ 08^s$, the motion was composed of vibrations of T=8.3 sec., max. 2a=0.051 mm mixed with smaller ones. [End portion.] The vibrations of T=6.8 sec., max. 2a=0.013 mm, were mixed with the small ones of T=2.1 sec.

Earthquake of Sept. 30th, 1912, *at* 9.34 *p.m.* The earthquake originated off the E. coast of Kazusa. Longit. Compt.; total duration$=15^m$. During the 1st 13.1 sec., the motion was very small. During the next 13.5 sec., the vibrations were larger: T =1.04 sec., max. 2a=0.012 mm. [Principal portion: duration$=1^m\ 41^s$.] During the 1st 30.8 sec., the slow vibrations of T=3.4 sec., max. 2a=0.029 mm, were mixed with some smaller ones. During the next 32.0 sec., the motion was largest and composed chiefly of the vibrations of T=1.8 sec., of which the max. 2a of 0.043 mm occurred at the commencement and at the end. During the remaining 38.0 sec., the vibrations of T=2.0 sec., max. 2a=0.016 mm, with mixture of quicker ones, were grouped into slow oscillations of T=6.6 sec. [End portion.] Vibrations of T=2.2 sec. were grouped into those of T=4.4 sec., max. 2a=0.014 mm.

110. *Distant eqkes observed at Asama Pasture Ground.*

Earthquake of Oct. 16th, 1913. This earthquake, which was slightly felt in Tokyo at $9^h\ 17^m\ 29^s$ a.m., originated near the south-eastern coast of the province of Kazusa, at a radial distance of about 210 km to the S50°E of the Asama-yama, so that the two horizontal components at the Asama Pasture Ground, oriented respectively in the directions at right angles and parallel to the line pointing to the crater, were approximately the longitudinal and transverse components with respect to the origin of the earthquake in question. Total earthquake duration $=2^m\ 40^s$. [Longitudinal or SSE-NNW Component.] During the 1st 6.9 sec., the motion was composed principally of quick vibrations of $T=0.29$ sec., max. $2a=0.0175$ mm. For the next 4.5 sec., the movements were slower. For the next 5.6 sec., the motion was most active, consisting of well defined quick vibrations of $T=0.24$ sec., max. $2a=0.0302$ mm, mixed more or less distinctly with those of $T=0.63$ sec. For the next 11.1 sec., the motion was composed principally of vibrations of $T=0.69$ sec., max. $2a=0.029$ mm, at first mixed with quick ones of $T=0.27$ sec., max. $2a=0.0207$ mm. For the next 13.2 sec., the movements were much smaller: $T=0.68$ sec., max. $2a=0.0156$ mm. The subsequent motion was very slight. [Transverse or ENE-WSW Component.] During the 1st 6.8 sec., the vibrations were, as in the other component, nearly uniform: $T=0.29$ sec., max. $2a=0.0136$ mm. For the next 8.0 sec., the motion was gentle and composed of slower movements of max. $2a=0.0086$ mm. The next 10.3 sec. forms the most active portion of the earthquake and consisted of the quick vibrations of $T=0.24$ sec., max. $2a=0.038$ mm, mixed with those of $T=0.64$ sec. During the next 20.4 sec., the motion was composed principally of the slow vibrations; the large ones (max. $2a=0.030$ mm), which occurred at the commencement having the period of 0.72 sec. The subsequent motion was smaller.

Earthquake of Nov. 14th, 1913, *at* $11^h\ 4^m$ *a.m.* This earthquake was felt slightly at Kofu, and registered as an unfelt shaking at the meteorological observatories of Fukushima, Utsunomiya, Mito, Kumagai, Yokohama, Numazu, Matsumoto, and Tokyo; the time of occurrence at the Seismological Institute, where the preliminary tremor lasted about 13 sec., being $11^h\ 4^m\ 19^s$ a.m. The origin of disturbance was in the north-western part of the province of Musashi, i.e. at a distance of about 50 km to the SE of the Asama-yama. The two horizontal pendulums of the tremor-recorder at the Asama Pasture Ground oriented for the longitudinal and the transverse directions with respect to the movements emanating from the volcanic centre, registered in the present case respectively the approximate transverse and the longitudinal components of the earthquake motion. The earthquake had been preceded by a small fore-shock $1^m\ 37^s$ before. Total duration=127 sec. [Longitudinal or SSE-NNW Component.] The vibrations were small for the 1st 4.0 sec.: T=1.0 sec., 2a=0.0037 mm. For the next 31.2 sec., the motion was composed of the vibrations of T=0.73 sec., max. 2a=0.026 mm, mixed with some quick movements of T=0.26 sec., and grouped more or less definitely into slow oscillations of about 5.3 sec. period. During the remaining 25.2 sec. of the principal portion, the vibrations were free from the superposition of the quick movements and a little smaller than before: T=0.83 sec., max. 2a=0.026 mm. The subsequent motion was much smaller. [Transverse or ENE-WSW Component.] The motion, which was distinctly indicated first from 5.4 sec. after the commencement of the earthquake, consisted, for the next 30.8 sec., of the vibrations principally of T=0.71 sec., max. 2a=0.031 mm, with the mixture of some quick movements. During the remaining 28.9 sec. of the principal portion, the vibrations, which became a little smaller, were free from the superposition of the latter, being, as before, grouped into slow oscillations of T=6.3 sec. [Comparison of Longitudinal and Transverse Components.] The first distinct movement was indicated 5.4 sec. earlier in the longitudinal than in the transverse component. There was, however, no special difference between the two with respect to the individual vibrations composing the earthquake motion.

111. ***Remarks on ordinary earthquakes and non-eruptive volcanic earthquakes observed at Yuno-taira and Asama Pasture Ground.*** The mean values of the different group periods (Tables XXVI and XXVII) found in the different ordinary earthquakes observed at Yuno-taira and at the Asama Pasture Ground (§§ 108 to 110) are as follows:—

	Yuno-taira.	Asama Pasture Ground
(i)	26.4 sec.	— sec.
(ii)	6.0	5.4
(iii)	2.2	—
(iv)	0.95	0.76
(v)	0.38	0.28

The periods of the most frequently occurring vibrations are (iii) and (iv), namely, 2.2 sec. and 0.95 sec. at Yuno-taira, and (iv) and (v), namely, 0.76 sec. and 0.28 sec. at the Asama Pasture Ground. The period (ii), namely, 6.0 or 5.4 sec., is probably of the nature of the pulsatory oscillations. Had the earthquakes been sufficiently large, there would have been also periods much longer than (i), or 26.4 sec.

As referred to in § 99, the periods of vibration, (ii) to (v), in the ordinary earthquakes are also found in the shakings caused by the Asama-yama eruptions.

From the analysis of a few seismograms given in Chapter X, it seems likely that the motion of the non-eruptive volcanic earthquakes also contains a number of periods similar to those found in the ordinary shocks. The duration of the earthquake motion due to the individual eruptions, whether strong or weak, was always short, being at the different Asama-yama stations less than 260 sec. In the case of the non-eruptive volcanic shocks of sharp character, as described in § 103, the total duration was much shorter; the duration of the principal portion being, in particular, momentary, so to speak, and varying from 2.0 to 6.5 sec. The disturbances of this nature, whose record on a small time-scale smoked-paper consists apparently of a single jerk or dot, are each made up of course of a number of very quickly decreasing vibrations.

TABLE XXVI. PERIODS* OF VIBRATION IN ORDINARY EARTHQUAKES OBSERVED AT THE ASAMA PASTURE GROUND.

(Mean values are printed in thick figures.)

sec.	sec.	mm.	sec.	mm.
6.3	1.00	(0.0037)	0.32	(0.048)
5.4	0.92	(0.016)	0.30	(0.044)
5.3	0.85	(0.025)	0.29	(0.018)
4.6	0.83	(0.026)	0.29	(0.014)
5.4	0.79	(0.003)	0.27	(0.021)
	0.78		0.26	
	0.73	(0.026)	0.24	(0.030)
	0.72	(0.030)	0.24	(0.038)
	0.71	(0.031)	**0.28**	
	0.71			
	0.69	(0.029)		
	0.68	(0.016)		
	0.64			
	0.63			
	0.76			

* Collected from the two components.

TABLE XXVII. PERIODS* OF VIBRATION IN ORDINARY EARTHQUAKES OBSERVED AT YUNO-TAIRA.

(Mean values are printed in thick figures.)

Preliminary Tremor.	Principal Portion.		End Portion.
sec. mm.	sec.	mm. sec.	sec. mm.
2.4 (0.01)	26.4	1.10 (0.32)	6.8 (0.013)
1.5 (0.013)	mm.	1.07	4.4
	8.3 (0.051)	1.00 (0.10)	**5.6**
1.04 (0.012)	6.6	1.00 (0.061)	
	5.5 (0.036)	0.96 (0.18)	2.9 (0.003)
0.55 (0.002)	4.4	0.93 (0.054)	2.9 (0.0054)
0.27	**6.2**	0.91 (0.065)	2.3
		0.87	2.2
	3.4 (0.029)	**0.98**	2.1
	2.7		1.5
	2.6 (0.031)	0.38	1.4 (0.013)
	2.5	0.35 (0.025)	**2.2**
	2.2	**0.37**	0.93 (0.011)
	2.0 (0.016)		0.85
	2.0		0.84 (0.0033)
	1.9		**0.87**
	1.8 (0.043)		0.33
	2.3		

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* Relating to the ENE-WSW component.

CHAPTER XII. TROMOMETER OBSERVATIONS IN TOKYO OF ASAMA-YAMA ERUPTIONS.

112. The earth shakings caused by the strong Asama-yama eruptions, whether detonative or non-detonative, are clearly registered by the tromometers at the Seismological Institute in Tokyo, provided the pulsatory oscillations are not too large to confuse the earthquake motion. In the next two §§ I give the analysis of the EW component records from the 120-times tromometer, (magnified photographically to the resultant enlargement of about 1,000 times), of the following eight Asama-yama eruptions:—

(i) Explosion of May 31st, 1909 ; 11.25 p.m.
(ii) ,, May 8th, 1911 ; 3.27 ,,
(iii) ,, June 26th, 1913 ; 11.41 ,,
(iv) ,, July 13th, ,, ; 4.01 ,,
(v) ,, ,, 19th, ,, ; 0.54 ,,
(vi) ,, Aug. 12th, ,, ; 11.20 ,,
(vii) Non-detonative eruption of Nov. 6th, 1913 ; 1.21 p.m.
(viii) ,, ,, ,, ,, 20th, ,, ; 3.40 p.m.

The eruptions, (i) to (vi), were strong detonative explosions, while the two others, (vii) and (viii), were non-detonative outbursts.

113. ***Strong Asama-yama eruptions observed in Tokyo: EW component tromometer records.*** Explosions, (i) to (vi).

(i). *Explosion of May 31st,* 1909, *at* 11.25 *p.m.* Total duration=3 m 45 s. The motion, which was somewhat confused by the small pulsatory oscillations, was small for about 23.5 sec. The maximum phase lasted 55 sec. and began with two vibrations ($2a=0.004$ mm) of periods 5.6 and 4.2 sec. respectively. The next 5 vibrations (max. $2a=0.005$ mm) with the T of 2.9 sec. lasted together 14.6 sec. The next 4 vibrations were smaller and lasted 8.5 sec.: $T=2.1$ sec. Then followed 2 slow vibrations of $T=4.2$

sec. During the next 14.1 sec., the vibrations were again a little quicker: T=3.1 sec. The *pulsatory oscillations* existing about the time of the earthquake motion had the T of 4.4 sec., with the max. 2a of 0.002 mm.

(ii) *Explosion of May 8th*, 1911, *at* 3.27 *p.m.* Total duration=7 m 27 s. For the 1st 24.3 sec.,* the motion was small, there being traces of slow vibrations of T=5.3 sec. [Maximum phase: duration=84 sec.] For the 1st 13.1 sec., there were three well defined vibrations of T=4.4 sec., the 2nd of which had the max. 2a of 0.0164 mm and occurred 31.2 sec. after the commencement of the earthquake. For the next 20.0 sec., the motion was small, the vibrations of T=1.9 sec. being mixed with slower ones. Then, 51.2 sec. from the commencement, took place two large slow vibrations of T=5.6 sec., 2a=0.0101 mm, lasting together 11.1 sec. During the next 12.0 sec. there were 4 vibrations, which were again a little quicker: T=3.0 sec., 2a=0.0097 mm. For the next 28.2 sec., the period was T=3.1 sec., the max. 2a being 0.0076 mm. Thereafter, the motion was much smaller. The *pulsatory oscillations* immediately before the earthquake indicated an average period of 3.1 sec. (max. 2a=0.0021 mm).

(iii) *Explosion of June 26th*, 1913, *at* 11.41 *p.m.* Total duration=5 m 58 s apprx. For the 1st 20.5 sec.,* the motion consisted of three slow vibrations of T=6.8 sec. and of gradually increasing amplitude. [Maximum phase: duration=50 sec.] The 1st 1½ vibrations had the T of 3.7 sec., whose 1st displacement was directed eastwards, and whose 2nd had the max. 2a of 0.0193 mm. For the next 23.7 sec., the motion was smaller, being composed of about 9 vibrations of T=2.6 sec., max. 2a=0.0093 mm. For the next 20.5 sec., the motion became again larger, being composed of 4 vibrations of T=3.8 sec., max. 2a=0.0147 mm, and 2 smaller ones of T=2.7 sec. The subsequent motion was principally composed of vibrations of T=3.7 sec. The *pulsatory oscillations* preceding and following the earthquake motion in question also indicated, amongst the others, the periods of 3.7 and 2.7 sec., the max. 2a being 0.0039 mm. The average period of the *micro-tremors* was about 0.6 sec.

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* The commencement is obscure, on account of the presence of pulsatory oscillations.

(iv) *Explosion of July 13th*, 1913, *at* 4.01 *p.m.* Total duration= 6^{m} 25^{s} apprx. For the 1st 12.1 sec., the motion was small: T= 2.3 sec. For the next 17.5 sec., there were 3 slow vibrations of T=6.7 sec. and of increasing amplitude. [Maximum phase: duration=45 sec.] For the 1st 5.6 sec., there took place 1½ large vibrations of T=3.7 sec., and 2a=0.0156 mm. For the next 20.1 sec., the motion consisted of 9 small and nearly equal vibrations of T=2.2 sec. (max. 2a=0.0084 mm), grouped into those of double length. For the next 19.0 sec., the motion became again large and comprised 6 vibrations of T=3.2 sec., max. 2a=0.0124 mm. In the subsequent portion, the vibrations were smaller and had the T of 3.3 sec., grouped into those of period of double length.

(v) *Explosion of July 19th*, 1913, *at* 0.54 *p.m.* Total duration $=7^{m}$ 35^{s} apprx. For the 1st 31.1 sec., the vibrations were small. [Maximum phase: duration=51 sec.] First there took place 1½ vibrations of T=4.6 sec., 2a=0.026 mm. For the next 22.3 sec., there were 9 quicker and smaller vibrations of T=2.5 sec., 2a= 0.0143 mm. For the next 21.9 sec., the motion became again active, there being 4 large vibrations (2a=0.0141 mm) of T=3.8 sec., and 2 small ones (2a=0.0099 mm) of T=3.3 sec. Thereafter the vibrations were small: 2a = 0.008 mm, T = 3.3 sec., T =26 sec. The period of the *pulsatory oscillations*, which occurred immediately before the earthquake, were 3.3 and 2.6 sec., (max. 2a=

0.0057 mm). The period of the *micro-tremors* was 0.61 sec.

(vi) *Explosion of Aug. 12th,* 1913, *at* 11.20 *p.m.* Total duration$=7^{m}$ apprx. During the 1st 31.9 sec., there were traces of the vibrations of T=6.2 sec., 4.4 sec., and 3.3 sec. [Maximum phase: duration=50 sec.] The motion began with 3 displacements, which lasted 7.6 sec., and the 1st two of which formed the max. vibrations of T=5.2 sec., 2a=0.0275 mm. For the next 23.1 sec., the motion was small, (max. 2a=0.0114 mm), comprising 10 vibrations of different periods. Then there took place two large vibrations of T=3.8 sec., 2a=0.0242 mm, lasting together 7.5 sec. During the next 11.9 sec., there were 4 vibrations of T=3.0 sec., 2a=0.0145 mm. In the subsequent portion, the motion was smaller: T=3.3 sec., max. 2a=0.0104 mm. The well-defined *pulsatory oscillations*, which occurred before and after the earthquake motion, indicated an average period of 4.1 sec., with the max. 2a of 0.0088 mm.

114. *Non-detonative eruptions registered in Tokyo.*

(vii) *Eruption of Nov. 6th,* 1913, *at* 1.21 *p.m.* Tromometer Diagram; EW Component. Total duration$=6^{m}\ 14^{s}$. The time interval between the commencement of the preliminary tremor and the beginning of the maximum phase was 31.3 sec. [Principal portion: duration=66.0 sec.] The motion was unusually large, and during the 1st 9.7 sec., there were 1½ vibrations of T=6.5 sec., 2a=0.024 mm. During the next 11.0 sec., there were 2 nearly equal vibrations of slightly shorter period: T=5.5 sec., 2a=0.027 mm. Then followed 6 quicker vibrations of decreasing magnitude and of T=2.9 sec., which together lasted 17.4 sec., and the 1st of which had the max. (absolute) 2a of 0.031 mm. Then, for the next 15.2 sec., there were again 2 slow vibrations of T=7.6 sec., 2a=0.019 mm, with some superposition of small movements. During the remaining 13.6 sec. of the principal portion, there were 4½ quick vibrations of T=3.0 sec., 2a=0.025 mm. [End portion.] During the 1st 56.7 sec., the motion was nearly constant in amplitude and was composed of slow vibrations of T =5.7 sec., 2a=0.014 mm, with the superposition of some quicker movements. Thereafter the motion was much smaller, the principal period being about 3.6 sec. The period of the principal *pulsatory oscillations*, which existed before and after the earthquake motion was about 5.0 sec.

(viii.) *Eruption of Nov. 20th*, 1913, *at* 3. 40 *p.m.* Tromometer Diagrams: EW, NS, and Vertical Components. Total duration=7^m apprx. The motion due to this eruption was unusually large, but the preliminary and end portions were confused by the presence of pulsatory oscillations.

EW Component. The maximum phase, which lasted 74.2 sec., began with three vibrations of T=5.3 sec., followed by three others of T=3.7 sec. Then took place six vibrations of T=2.7 sec., the 1st three of which were large (max. 2a=0.022 mm). The two next vibrations were slow (T=7.0 sec.) and mixed with smaller ones. Then followed again five quicker movements of T=3.1 sec., max. 2a=0.025 mm. The principal *pulsatory oscillations* (max. 2a= 0.009 mm) had the T of 6.7 sec., and were mixed with small vibrations of T=2.7 sec. There were cases where the pulsatory oscillations consisted of regular movements of T=3.6 sec.

NS Component. The most active portion, 37.3 sec. in duration, was composed of the vibrations of T=3.0 sec., max. 2a= 0.021 mm.

Vertical Component. The motion was distinctly indicated for 70 sec., and consisted of the vibrations of T=3.0 sec., max. 2a= 0.02 mm.

115. ***Remarks on Tokyo registrations of Asama-yama eruptions.*** The diagrams of the different Asama-yama eruptions obtained in Tokyo are mutually similar, almost vibration for vibration. The ordinary preliminary tremor and the earlier portion of the principal portion are generally not well pronounced in the cases under consideration, while the maximum motion phase is always distinctly indicated. Thus, the duration of the preliminary portion, i.e., the preliminary tremor and the earlier stage of the principal portion preceding the maximum phase, varied, in the four well-defined cases, between 29.6 and 31.9 sec., giving the average value of 31.0 sec. The maximum phase lasted from 45 to 84.4 sec., with the average interval of 59.4 sec.; while the average total duration of the earthquake motion was about 7^m.

TABLE XXVIII. TOKYO OBSERVATIONS: DURATIONS OF THE DIFFERENT PHASES OF MOTION.

Preliminary Portion.	Maximum Phase.	Total Earthquake.
29.6 sec.	45 sec.	6 min. 00* sec.
31.1	50	6 14
31.3	50	6 25*
31.9	51	7 00*
	55	7 00*
	66	7 27
	74.2	7 35*
	84.4	
31.0	**59.5**	——

* Only approximate. Mean values are printed in thick figures.

It will be noticed that the total duration and the duration of the maximum phase in Tokyo of the Asama-yama eruptions, being in the mean respectively about 7 min. and 1 min., are much longer than the total duration and the duration of the specially strong part of the disturbances observed on the mountain itself (Yuno-taira), where the mean values of the duration in question were 118 and 15 sec.

The mean periods of vibrations (Table XXIX) in the different phases of the earthquake motion, compared with those of the pulsatory oscillations existing immediately before or after the latter, were as follows:—

Phase of Motion.		Period.	
Earthquake (Eruption)	Preliminary portion ..	6.0 sec.	2.8 sec.
	Maximum phase	5.5	3.0
	End portion	—	3.3
Pulsatory Oscillation		5.1	3.1
Mean		**5.5**	**3.1**

Thus the two groups of periods, whose mean values are respectively 5.5 and 3.1 sec., were found in the earthquake vibrations caused by the Asama-yama eruptions as well as in the pulsatory oscillations. In other words, the seismic movements in question are nothing else than the magnifications of the natural vibrations of the ground, just as the "tsunami", or destructive sea-waves, consist in the amplification of the water oscillations existing more or less at all times.

TABLE XXIX. TOKYO OBSERVATIONS: PERIODS OF VIBRATION OF THE EARTHQUAKES DUE TO THE ASAMA-YAMA ERUPTIONS COMPARED WITH THOSE OF THE PULSATORY OSCILLATIONS.*

Asama-yama Earthquakes.				Pulsatory Oscillations.
Preliminary Tremor.	Principal Portion.		End Portion.	
sec. mm.	sec. mm	sec. mm.	sec. mm.	sec mm.
6.8	7.6 (0.019)	3.8 (0.0147)	5.7 (0.014)	6.7
6.7	7.0	3.8 (0.0141)		5.0
6.5 (0.024)	6.5 (0.024)	3.8 (0.0242)		4.4 (0.0025)
6.2	5.6 (0.010)	3.7 (0.0193)	3.7	4.1 (0.0088)
5.3	5.6 (0.004)	3.7	3.3	**5.1**
4.4	5.5 (0.027)	3.7 (0.0156)	3.3 (0.008)	
6.0	5.3	3.3 (0.0100)	3.3 (0.010)	3.7 (0.0039)
	5.2 (0.0275)	3.2 (0.0124)	2.6 (0.008)	3.6
3.3	4.6 (0.026)	3.1	**3.2**	3.3 (0.0057)
2.3	4.4 (0.0164)	3.1 (0.0250)		3.1 (0.0021)
2.8	4.2	3.1 (0.0076)		2.7 (0.0039)
	4.2	3.0 (0.0145)		2.7
	5.5	3.0 (0.010)		2.6 (0.0057)
		3.0 (0.025)		**3.1**
		2.9 (0.031)		
		2.9 (0.005)		
		2.7		
		2.7 (0.022)		
		2.6 (0.0093)		
		2.5 (0.0143)		
		2.2 (0.0084)		
		2.1		
		1.9		
		3.0		

---

* Mean values are printed in thick figures. 2a corresponding to a given period is enclosed within brackets.

The values of the max. 2a in the EW component of the different eruptions are given below:

Eruption.		Max. 2a. (in Tokyo)	2nd Displacement of the Initial Vibration. (Yuno-taira.)
			mm
(i)	May 31st, 1909.	0.005 mm	—
(ii)	May 8th, 1911,	0.0164	—
(iii)	June 26th, 1913. (11 p.m.)	0.0193	0.093
(iv)	July 13th, „	0.0156	0.123
(v)	„ 19th, „	0.026	0.127
(vi)	Aug. 12th, „ (11 p.m.)	0.0275	0.217
(vii)	Nov. 6th, „	0.031	—
(viii)	„ 20th, „	0.025	0.019 (Asama Pasture Ground.)

From the above list it will be observed that the strong eruption of Aug. 12th, 1913, whose "initial vibration" was large, indicated also a comparatively large motion in Tokyo; while the non-detonative eruptions on Nov. 6th and 20th, 1913, with or without the "initial vibration," caused a large amount of motion in the latter. Again, the explosion of May 8th, 1911, whose sound area was quite extensive, was propagated, in a very insignificant seismic manner. It is likely that the greatest earthquake motion is produced by the long-continued eruptions, which, with little accompanyment of the surface phenomena of a loud detonation, gives out a considerable amount of the smokes and ashes.

116. ***Time of occurrence in Tokyo.*** In the following table I give a comparison of the time (t_0) of commencement, at the Yuno-taira observatory on the Asama-yama, of the earthquake motion caused by the different strong eruptions and the time (t_m)

of appearance at the Seismological Institute, in Tokyo, of the maximum phase of motion due to the same cause of disturbance, with the value of the time difference $\delta t_m = t_m - t_0$; the time determinations in question having been made with a great accuracy.

Eruption.	t_0 {Yuno-taira, on Asama-yama.}	t_m {Maximum Phase in Tokyo.}	$\delta t_m = t_m - t_0$.
	h m s	h m s	m s
June 26th.	11 41 59 p.m.	11 43 13 p.m.	1 14
July 13th.	4 01 19 p.m.	4 02 36 p.m.	1 17
„ 18th.	2 08 25 a.m.	2 09 36 a.m.	1 11
„ 19th.	0 54 03 p.m.	0 55 16 p.m.	1 13
Aug. 12th.	11 20 33 p.m.	11 21 46 p.m.	1 13
Mean.	——	——	1 13.6

According to the above table, the difference between the time of the earthquake commencement at Yuno-taira and that of the maximum phase in Tokyo varied in the five cases between $1^m\ 11^s$ and $1^m\ 17^s$, giving the mean value of $\delta t_m = 1^m\ 13.^s6$.

As the duration in Tokyo of the preliminary tremor and the earlier part of the principal portion preceding the maximum phase is 31.0 sec., it follows that the interval between the time of the first occurrence of the earthquake motion at Yuno-taira and that at Tokyo Seismological Institute is $\delta t_0 = 1^m\ 13.^s6 - 31.^s0 = 42.^s6$.

117. ***"Sound shock" observed in Tokyo.*** In those cases, in which the detonations of the Asama-yama explosions were perceived in Tokyo, the arrival of the sound waves was marked on the tromometer diagrams by the appearance of the "sound shock," or a disturbance consisting of a series of extremely minute quick tremors a definite time interval after the earthquake occurrence. I describe in this § the EW component tromometer records of the

" sound shocks " photographically enlarged to the resultant magnification of 1,000 to 3,000 times, obtained on the occasions of the following three explosions: (i), Dec. 7th, 1909; (ii), May 8th, 1911; and (iii), Aug. 12th, 1913. There were several other cases in which the sound shock was confused by the existence of conspicuous pulsatory oscillations. The illustrative diagrams are given in Figs. 68 and 69.

The position of the Seismological Institute is as follows:

$\varphi = 35° \ 42' \ 40''$ N; $\lambda = 139° \ 45' \ 48''$ E.(1)

Radial Distance from the Asama-yama = 135.40 km.(2)

(i) *Explosion of Dec. 7th,* 1909. (Fig. 67.) Total duration of the " sound shock " = 45 sec. For the 1st 6.6 sec., the motion was small: T = 0.44 sec., max. 2a = 0.0015 mm. Then began the principal portion, and for the next 20.0 sec., the vibrations were active and had the period of 0.40 sec., the greatest 2a of 0.0105 mm having occurred 16.6 sec. from the commencement of the " sound shock ". The subsequent motion was very small, the period being 0.40 sec. The arrival of the detonation or audible sound shock probably coincided with the commencement of the principal portion.

(ii) *Explosion of May 8th,* 1911: Tromometer EW Component Diagram. (See Fig. 69.) Total duration of the " sound shock " = 44 sec. The preliminary portion, whose commencement was not well marked on account of the presence of pulsatory oscillations and micro-tremors, lasted about 12.5 sec., consisting of quick small movements of T = 0.42 sec. Then at 3.34.38 p.m. the motion became suddenly large, denoting probably the moment of arrival of the detonation. The vibrations remained active for the next 11.2 sec., with the average T of 0.40 sec.; the max. 2a of 0.0076 mm occurring at the commencement of this phase. The subsequent vibrations were much smaller, the period being 0.42 sec. The pulsatory oscillations at the time of the disturbance had the period of 3.3 sec., with the max. 2a of 0.0038 mm.

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(1) Measured from the War Department Map of 1: 10,000 scale.

(2) The position of the Asama-yama crater taken from the 1: 200,000 scale map of the Imperial Geological Survey being $\varphi = 36° \ 24' \ 30''$ N, $\lambda = 138° \ 32'$ E.

As noted in the *Bulletin*, Vol. VI, p. 87, the detonation, which was perceived by the present author at the Seismological Institute, was made up of loud rushing sounds, commencing at $3^h 34^m 37^s$ p.m. and lasting about 10 sec., during which interval the windows were shaken considerably as by strong winds or by an earthquake of moderate intensity.

(iii) *Explosion of Aug. 12th*, 1913, *at* 11. 20 *p.m.* The "sound shock", whose total duration was only about 23 sec., was very slight, its first indication being at $t_s = 11^h\ 27^m\ 05^s.7$ p.m. 1.3 sec. later on, namely, at $11^h\ 27^m\ 07^s$ p.m., the motion became larger (max. $2a = 0.0036$ mm), corresponding to the arrival of the audible sound waves. The duration of the principal portion was about 2.5 sec. At the Seismological Institute, the time of commencement of the maximum phase in the EW component diagrams was at $t_m = 11^h\ 21^m\ 45.^s5$ p.m.; that of the earthquake commencement being, therefore, $t_1 = 11^h\ 21^m\ 14.^s5$ p.m. The time difference between the arrivals of the earthquake motion and the sound wave in Tokyo (Seismological Institute) is thus $= t_s - t_1 = 5^m\ 31^s$.

The present author, who was at the time writing by a desk with a pocket chronometer before him, in his house (Sekiguchi-daimachi, Koishikawa District), heard the sound of the eruption in question, which was like that caused by the fall of a heavy weight on the ground and was less than 1 sec. in duration, the doors and *shoji* being slightly shaken. The time of the arrival of the sound was $11^h\ 26^m\ 58^s$ p.m., the place of observation

($\varphi = 35° 42' 40''.5$ N ; $\lambda = 139° 43' 32''.8$ E) being at the radial distance of 132.08^{km} from the Asama-yama. Thus the differences of the radial distances of, and of the times of arrival of the detonation at, the Seismological Institute and my house were respectively $135.40 - 132.08 = 3.32$ km, and $11^{\mathrm{h}}\,27^{\mathrm{m}}\,07^{\mathrm{s}} - 11^{\mathrm{h}}\,26^{\mathrm{m}}\,58^{\mathrm{s}} = 9$ sec., being mutually at a fair agreement.

In the three cases considered above, the values of the total duration were respectively 23 sec., 44 sec., and 45 sec.; while those of the principal portion were respectively 2.5 sec., 11.2 sec., and 20 sec. The principal vibration period varied between 0.40 and 0.44 sec., with the mean of 0.41 sec., the greatest value of the EW component max. 2a being 0.0105 mm.

The "sound shock", which appears on the tromometer diagrams in Tokyo only when the detonation is heard in the latter, seems to consist, not in the elastic shakings of the writing pointer of the tromometer under the influence of the air disturbances, but in the real movements of the ground due probably to the impact, or the change in the barometric pressure attending the propagation, of the explosive waves. The noon-gun of Tokyo, fired at a distance of 3 km from the Seismological Institute, is sometimes audibly very loud, giving, however, no "sound shock" record on the smoked paper. Again, the peals of thunders produce, even when very strong, no effects of the kind. It thus seems likely that the amount of energy involved in the sound waves of a strong Asama-yama explosion must be comparatively great, and capable of imparting minute tremors to the ground, as they radiate out. In the case of the explosion of Oct. 15th, 1913, registered at the Asama Pasture Ground, the "sound shock" generated in the transverse component the greatest vibration with the period characteristic to the place of observation.

CHAPTER XIII. BAROGRAPH OBSERVATIONS AT YUNO-TAIRA OF ASAMA-YAMA ERUPTIONS.

118. ***Open Barograph records of Asama-yama eruptions.*** In 1913 an attempt was made to obtain the open diagrams of the air disturbances caused by the strong Asama-yama eruptions, by means of a Richard's barograph, whose pointer was made to register with 5 times magnification on the smoked paper, just in the same way as in an Omori horizontal tromometer. (See Fig. 62.) By means of this arrangement a few of the eruptions were successfully registered at the Yuno-taira observatory and the Asama Pasture Ground,* as described below; the enlarged diagrams being reproduced in Figs. 63, 64 and 65. It may here be added that the proper vibration period of the pointer was quick and $=0.3$ sec. approximately.

119. ***Observation of explosions at Yuno-taira.*** The following three eruptions have been barographically registered at Yuno-taira on the quickly moving smoked paper :—

(i) Explosion of Aug. 12th, 1913; at $7^h 45^m$ p.m.
(ii) „ „ „ „ , „ ; „ 11 20 p.m.
(iii) „ May 5th, 1914; „ 0 33 a.m.

(i.) *Explosion of Aug. 12th, 1913, at* 7^h 45^m *p.m.* (Fig. 65.) The barometric disturbance, which occurred at 7^h 45^m 14.0^s p.m., began with a compressional wave, composed of the 1st displacement, or rise, of 2.8 mm and the 2nd displacement, or fall, of 3.2 mm, the two making up an oscillation of $T=2.7$ sec. Then followed a rarefactional wave about 4.4 sec. in period, and of the maximum double amplitude of 0.43 mm, there being a superposition of smaller vibrations of T=1.3 sec. The whole disturbance lasted 7.1 sec., the termination being also quite abrupt.

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* Same observations were repeated at the Sakura-jima on the occasion of the recent eruptions. The barographic diagrams were similar to those obtained at the Asama-yama stations.

The 1st displacement of the "initial vibration" of the corresponding earthquake motion at Yuno-taira took place at $7^h\ 45^m\ 07.6^s$; the 2nd displacement appearing 0.7 sec. later on (§ 61). Consequently the time interval between the occurrence of the detonation and that of the explosive outward motion of the ground was 5.7 sec.

(ii) *Explosion of Aug. 12th,* 1913, *at* $11^h\ 20^m$ *p.m.* In the smoked paper diagram, the barometric disturbance began at $11^h\ 20^m\ 40.4^s$ p.m. with a sudden rise of over 11 mm, the writing index of the instrument having thereby been thrown off the recorder. The counter motion seems to have been about 2 mm greater than the preceding.

In the ordinary Richard's barogram, the rise and fall of the pressure amounted to 14.2 and 16.5 mm respectively.

The commencement at Yuno-taira of the earthquake motion was at $11^h\ 20^m\ 32.9^s$ p.m., the 2nd displacement of the "initial vibration" taking place 1.5 sec. later on. Thus there was a time interval of 6.0 sec. between the occurrence of the detonation and that of the explosive outward motion of the ground.

(iii) *Explosion of May 5th,* 1914, *at* 0.33 *a.m.* (See Fig. 64.) The exact time of commencement of the barometric disturbance was $t=0^h\ 33^m\ 10.3^s$ a.m. or 6.9 and 5.2 sec. respectively after the moment of arrival of the 1st earthquake movement and the displacement corresponding to the actual beginning of the explosion; the time of commencement of the earthquake at Yuno-taira being $0^h\ 33^m\ 03.4^s$ a.m. The 1st barometric effect consisted in an abrupt increase of the pressure amounting to 6.4 mm, followed by the decrease of 7.0 mm, together composing an atmospheric vibration of T=2.3 sec. Then followed a 2nd vibration of T=1.9 sec., and composed of increase=0.3 mm, and decrease=1.5 mm; these forming, with the 2nd displacement of the 1st, a total decrease of 8.3 mm, resulting in the diminution of 1.8 mm from the original level. The next two small vibrations of T=3.4 sec. practically brought the barometric disturbance to end. Total duration=12.3 sec.

120. *Observation of non-detonative eruptions.* In 1913 the following two of the non-detonative eruptions of the Asama-yama have been observed in the same barographical manner:—

(iv) At Yuno-taira ....Eruption of Aug. 15th, at 4.01 p.m.
(v) „ Asama Pasture Ground „ Nov. 20th, „ 3.40 p.m.

(iv) *Eruption of Aug. 15th, 1913, at about* 4^h *p.m.*, observed at Yuno-taira. (Fig. 63.) The barographic disturbance was essentially compressional and began at $4^h\ 01^m\ 16.5^s$ p.m. ($=t_b$) with pressure increase, which reached the amount of 0.31 mm in the course of 1.9 sec. For the next 7.2 sec., the pressure was gradually decreased by the amount of 0.015 mm. Then, for the next 10.4 sec., the barometric fluctuations became active, there being amongst the others, 6 vibrations of maximum range of 0.29 mm and of period of about 1.14 sec. So far the total duration was 19.5 sec. The disturbance was thereafter very small, continuing for further 8.8 sec.

The character of the barometric disturbance was in accordance with that of the eruption, which consisted, not in a single explosion, but of a powerful smoke emission of a long duration. In the diagram of the corresponding earthquake motion, there were very small introductory movements for some time interval, but the commencement of the well pronounced preliminary stage was at

$4^h\ 01^m\ 05.8^s$ p.m. ($=t_1$), while there was a slight increase in the amplitude 3.7 sec. later on, namely, at $4^h\ 01^m\ 09.5^s$ p.m. ($=t_2$). The intervals between these times of occurrence of the earthquake movements and that of the barograph disturbance were as follows:—

$$t_b - t_1 = 10.7 \text{ sec.,}$$
$$t_b - t_2 = \ 7.0 \ \text{,, ;}$$

the latter of these values being not much different from those found, in the cases of the three strong explosions considered in the preceding § for the interval between the detonation and the outward explosive motion of the ground. Thus the commencement of the barometric disturbance coincided very nearly with that of the generation of the vibrations forming the introductory part of the preliminary portion of the earthquake motion, and not with the subsequent stronger shock or larger movements.

(v) *Eruption of Nov. 20th,* 1913, *at* $3^h\ 40^m$ *p.m.*, observed at the Asama Pasture Ground. The barometric disturbance, which lasted 5.4 sec., was composed of the two slow vibrations of the average $T=2.7$ sec., (with trace of the superposition of very slight movements); the 1st and principal one being made up of a rise of 0.36 mm and a fall of an equal amount. The time of commencement was $3^h\ 40^m\ 58^s$ p.m. or 21 sec. after the arrival of the earthquake motion at the same observing place.

121. *Remarks on barographic observations at Yuno-taira.* In the three cases of the explosions considered in § 119, the time differences between the occurrence of the barometric disturbance and the commencements of the preliminary portion and the 2nd displacement (or the end of the 1st) of the "initial vibration" of the earthquake motion were as follows:—

Explosion.	Time difference between Barometric Disturbance and Commencement of	
	Preliminary Portion.	2nd displacement of "Initial Vibration."
(i) Aug. 12th, 1913.	6.4 sec.⁽¹⁾	5.7 sec.
(ii) " " "	7.5	6.0
(iii) May 5th, 1914.	6.9	5.2
Mean.	7.2⁽²⁾	5.6

(1) The preliminary portion was obliterated by the tremblings of the ground which existed beforehand.

(2) (i) is excluded in taking this mean.

Thus, at Yuno-taira the barometric disturbance arrived, in the mean, 5.6 sec. after the occurrence of the 2nd vibration of the "initial vibration," or the stage corresponding to the actual moment of the explosion, and 7.2 sec. after the commencement of the earthquake motion.

Now, according to the descriptions of the seismograms given in Chapter VI, the mean time differences between the appearance of the "sound shock" and the commencements of the preliminary portion and of the 2nd displacement of the "initial vibration" were at Yuno-taira respectively 7.3 and 5.8, being equal to the above found mean intervals respecting the barometric disturbance, as follows :—

Explosion. (1913)	Time difference between "Sound Shock" and Commencement of	
	Preliminary Portion.	2nd displacement of "Initial Vibration."
May 27th.	— sec.	6.0 sec.
" 29th.	7.0	5.9
June 17th.	7.6	6.2
" 26th, (11 p.m.)	—	6.1

Explosion. (1913)	Time difference between "Sound Shock" and Commencement of	
	Preliminary Portion.	2nd displacement of "Initial Vibration."
July 8th.	6.9 sec.	5.7 sec.
" 13th.	8.7	6.3
" 18th.	6.4	5.2
" 19th.	6.8	5.5
Aug. 12th, (11 p.m.)	7.6	6.0
May 5th, (1914).	—	5.4
Mean.	7.3	5,83

Thus the time moment of appearance of the "sound shock" on the tromometer diagram is perfectly identical with that of the air disturbance on the barogram.

The total durations of the barometric disturbance in the two explosions of Aug. 12th, 1913, (at 7 p.m.), and May 5th, 1914, were respectively 7.1 and 12.3 sec.; being in the latter case equal to the duration of the specially prominent earthquake motion.

The first and main portion of the barometric disturbance is always made up of an abrupt compressional displacement followed by a slightly greater counter motion, the two making up an oscillation of the mean period of about 2.5 sec. It is interesting that this period (T), is not at all very short, but sufficiently long and not much different from that of the "initial vibration" of the earthquake motion. Denoting the amount of the increase or decrease in the barometric height by δp, the average rate of the pressure change is $=2\delta p/T$. If, for instance, δp be 15 mm, as was nearly the case in the explosion of Aug. 12th, 1913, at 11 p.m., then the mean pressure change on 1 sq. metre area would be

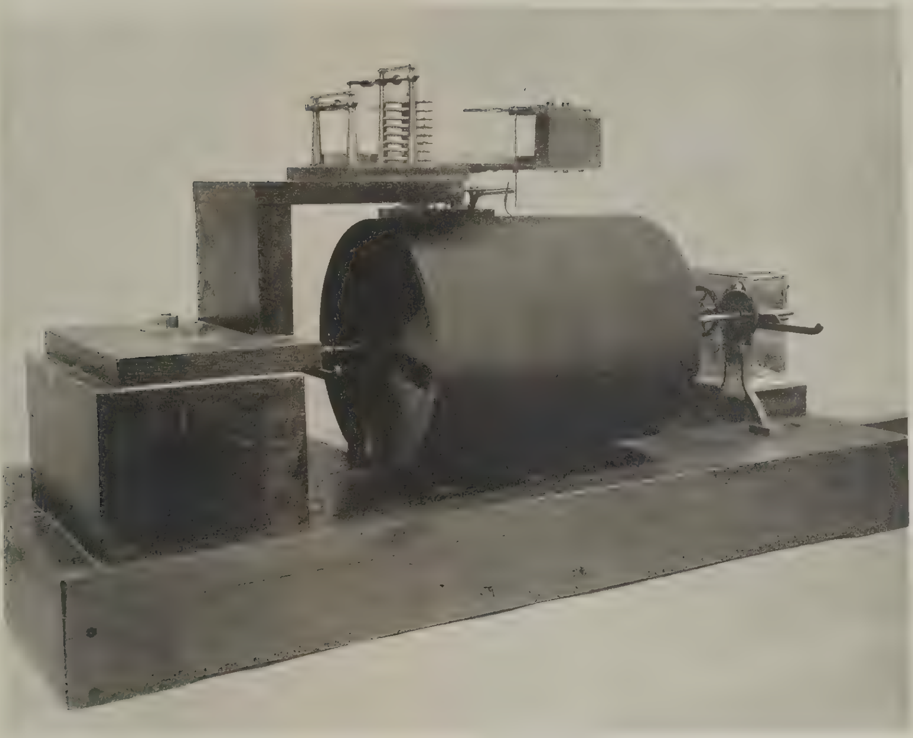

Fig. 62. **Barograph** adapted to a quick mechanical registration on smoked paper.

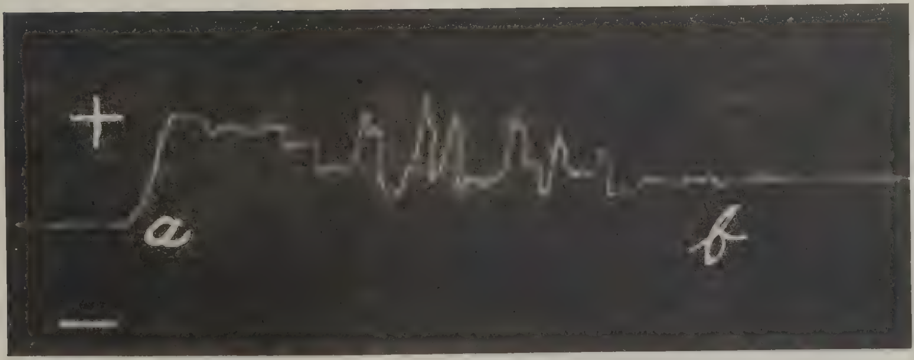

Fig. 63. **Yuno-taira Barogram of the non-detonative Asama-yama eruption on Aug. 15th, 1913, at 3. 58. 46 p.m.** Magnification = 44.
Time Scale: 1 minute = 192 mm.
(+)....Pressure Increase. (−) ...Pressure Decrease.

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Smoked-Paper Barograms of the Asama-yama Explosions observed at Yuno-taira. (+)....Pressure Increase. (−)....Pressure Decrease.

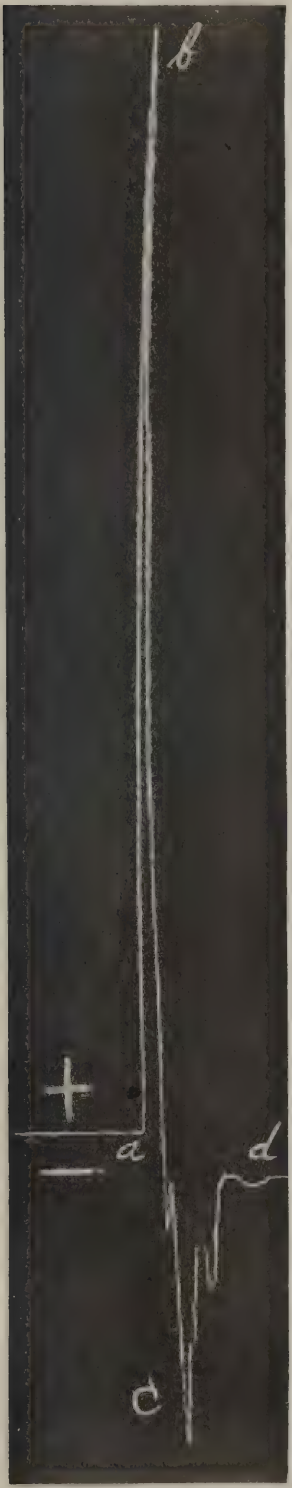

Fig. 64. **May 5th, 1914.**
Magnification = 23.
Time Scale: 1 min. = 79 mm.

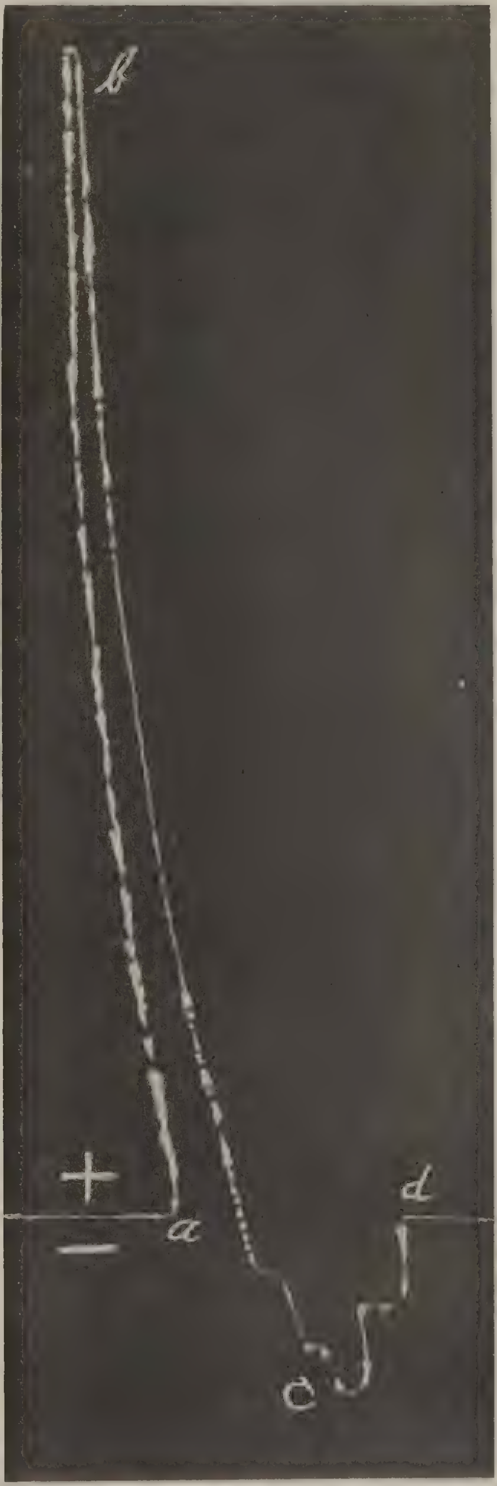

Fig. 65. **Aug. 12th, 1913**; $7\frac{3}{4}$ p.m.
Magnification = 56. Time Scale:
1 minute = 265 mm.

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$100 \times 100 \times \left(\frac{2 \times 1.5}{2.5}\right) \times 13.6 = 160$ kg per sec. This may be regarded as indicating the intensity of the sound wave of the explosion which caused the shakings of the building of the Yuno-taira observatory, being a sort of measure of the destructive capacity of the air concussion. The quick minute vibrations, which are doubtless mixed up with the principal oscillation above considered, although not indicated in the diagram, are probably the cause of the audible detonative sound.

From § 120 it is seen that the two powerful non-detonative eruptions of Aug. 15th (at 4 p.m.) and Nov. 20th, 1913, produced slight barometric disturbances, which consisted of a greater or smaller number of similar vibrations; the maximum amount of the barometric change being in these two cases 0.31 (at Yuno-taira) and 0.36 mm (at the Asama Pasture Ground). There existed the periods of 1.14 and 2.7 sec.

The barometric disturbances caused by the eruptions, both explosive and non-explosive, were essentially positive, i.e., consisted in the compressive effects, the rarefactional change beyond the level of equilibrium being very slight. (See also § 122.)

122. ***Explosions recorded on Richard's barograph.*** An ordinary Richard's barograph to the natural scale kept in the Yuno-taira observatory has recorded the different stronger explosions, the diagram consisting in each case of only a short single line, as shown in Figs. 66 and 67.

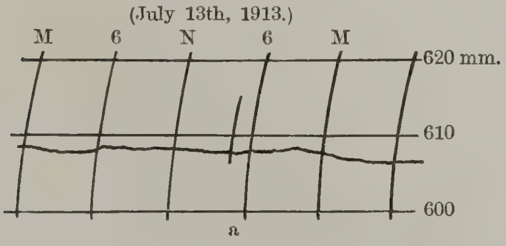
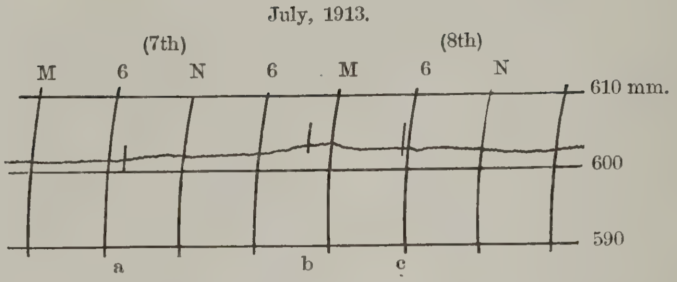


Fig. 66. (a)..Barometric disturbance caused by the explosion of the 13th, at 4.01 p.m.

Fig. 67.



(a), (b), (c)....Barometric disturbances caused by the explosions of the 7th, at 7.10 a.m. and 9.46 p.m., and of the 8th, at 5.25 a.m.

The barometric disturbance, i.e., the 1st increase and the 2nd decrease measured from the barograms, is tabulated below.

TABLE XXX. RICHARD'S BAROGRAPH RECORDS OF THE ASAMA-YAMA EXPLOSIONS. YUNO-TAIRA, 1913.

Date. (1913).	2nd displacement of the "initial vibration."	Barometric Disturbance.		
		Increase.	Decrease.	Ratio: $\frac{\text{Decrease.}}{\text{Increase.}}$
May 16.	0.102 mm.	2.8 mm.	4.0 mm.	1.4
„ 27.	0.062	3.6	4.2	1.2
„ 29.	0.098	3.0	3.6	1.2
June 20.	0.025	2.3	2.6	1.1
„ 26.	0.040	3.4	4.7	1.4
„ „	0.093	6.0	7.3	1.2
July 7.	0.037	2.7	4.0	1.5
„ „	0.080	3.3	4.1	1.2
„ 8.	0.088	3.5	4.3	1.2
„ 13.	0.123	7.7	9.6	1.3
„ 18.	0.116	3.4	4.7	1.4
„ 19.	0.127	9.6	12.5	1.3
Aug. 12.	0.050	1.6	—	—
„ „	0.217	14.2	16.3	1.2
Mean.	—	—	—	1.3

Vibrations due to the Sound-Shock of the Asama-yama Explosion registered by the Tromometer at the Seismological Institute, Tokyo.

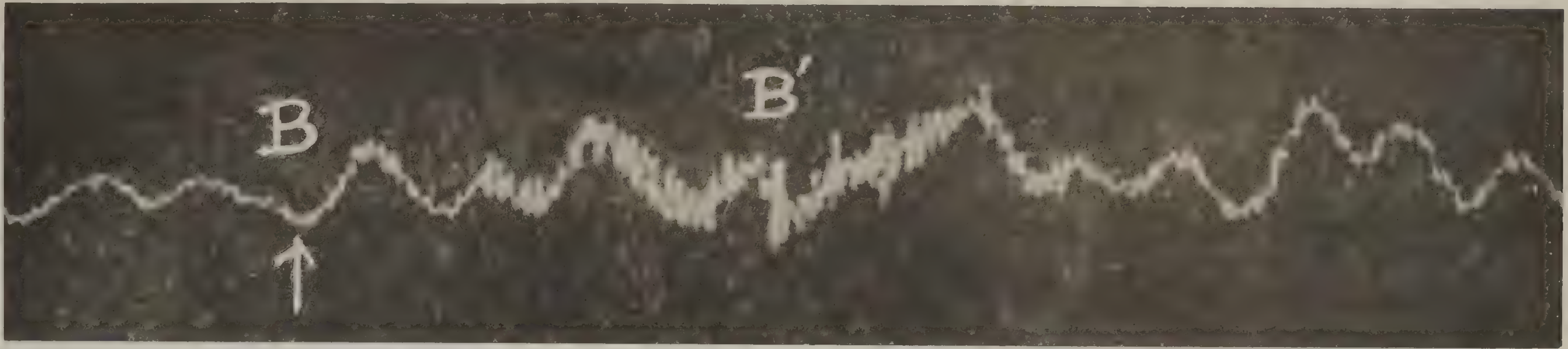


Fig. 68. Asama-yama Explosion of Dec. 7th, 1909. Magnification = 1100. Time Scale : 1 minute = 235 mm.

B = Approximate Commencement.
B′ = Maximum Phase.

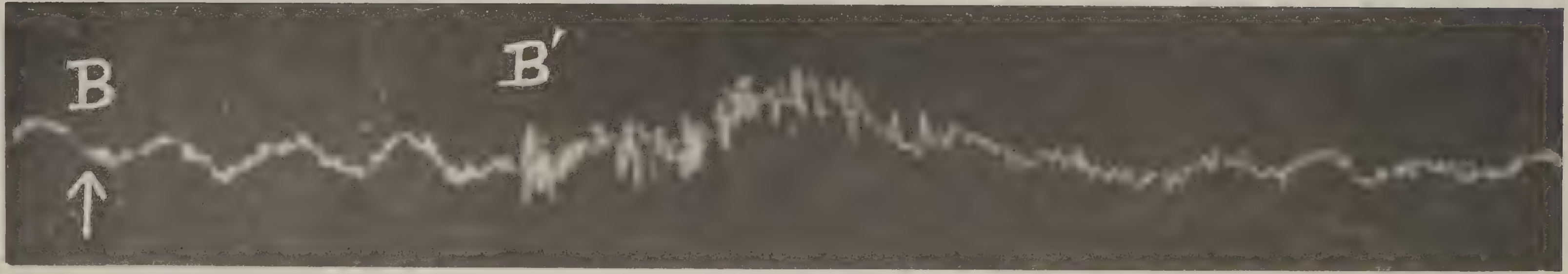


Fig. 69. Asama-yama Explosion of May 8th, 1911. Magnification = 1450. Time Scale : 1 minute = 287 mm.

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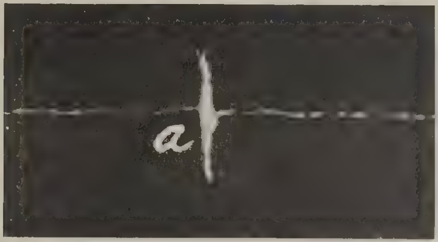
Non-Eruptive Volcanic Eqkes observed at Yuno-taira.

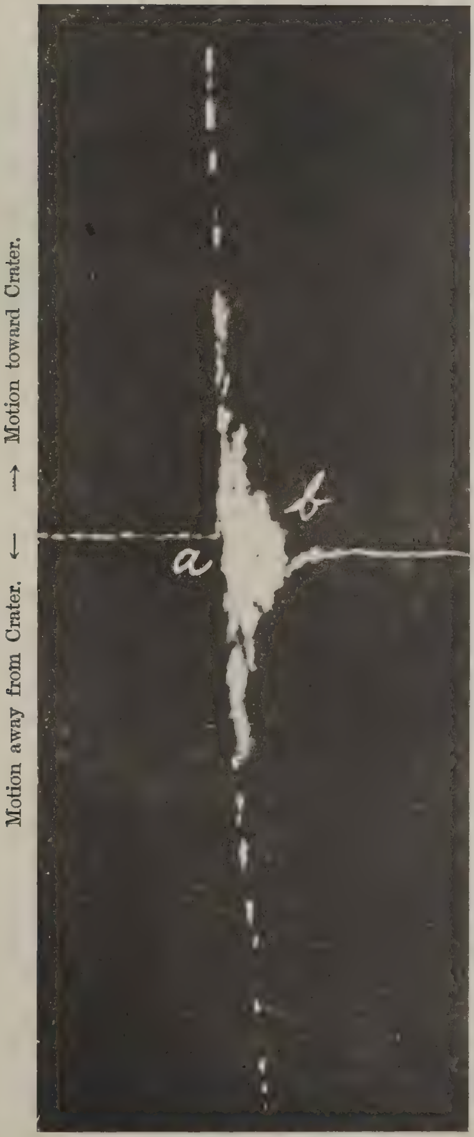


Time Scale: 1 min. = 82 mm.

Fig. 70. Tremor-recorder Transverse Component Diagram of a sensible Shock on July 1st, 1912, at 10. 09. 07 a.m.

Magnification = 585

[a....Commencement.]



Time Scale: 1 min. = 190mm.

Fig. 71. Tromometer Longitudinal Component Diagram of a shock on Sept. 13th, 1911, at 8.43.09 p.m.

Magnification = 1190.

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The largest barometric disturbances of about, or over, 10 mm were indicated in the three cases of July 13th and 19th, and Aug. 12th, 1913. The barographic record of the strong explosion of June 17th was unfortunately not taken at all. The 2nd or decrease change is on the average 1.3 times larger than the 1st or increase change.

Comparison with "Initial Vibration." From Table XXX it will be seen that the amount of the barometric disturbance varies with the range of the "initial vibration." Comparing the 2nd displacement of the latter, which accompanies the actual explosion, with the direct effect on the air disturbance, namely, the 1st barometric rise, we have :—

Barometric Disturbance. (1st Pressure Increase.)	"Initial Vibration." (2nd Displacement.)
14.2 mm.	0.217 mm.
9.6	0.127
7.7	0.123
6.0	0.093
3.0*	0.070*

* Meaned from the 10 cases in which the barometric increase was less than 4 mm.

The "initial vibration," the range of whose 2nd (or 1st) displacement increases with the amount of the barometric disturbance, may thus probably be taken as being proportional to the intensity of the explosive effect. Seismically, the "initial vibration" seems to possess no necessary, or at least, no simple, relation to the intensity of the subsequent earthquake motion.

123. ***Barometric disturbance and extension of sound area.*** In the following table I give a comparison of the extension of the total sound area and the 1st displacement of the barometric disturbance recorded by the Richard's barograph (Table XXX), arranged in order of magnitude of the latter.

Group.	Explosion.	Barometric Disturbance. (1st Displacement, or Increase).	Total Sound Area.
i	Aug. 12th (11 p.m.)	14.2 mm.	35,940 sq. km.
	July 19th	9.6	19,050
	,, 13th	7.7	18,250
	June 26th (11 p.m.)	6.0	15,750
ii	June 26th (8 a.m.)	3.4	12,610
	May 29th	3.0	19,370
	,, 16th	2.8	7,240
	June 20th	2.3	19,560

Thus, of the group (i) explosions, with the larger barometric disturbance, that on Aug. 12th had very extensive sound area. On the other hand, the explosions of the (ii) group, with the smaller barometric disturbance, had the sound areas of about the same extension as the rest of the (i) group. This seems to show that the extent of the sound area does not depend simply on the intensity of the detonation at the origin.

CHAPTER XIV. PROPAGATION VELOCITIES OF VOLCANIC DETONATION AND EARTHQUAKE MOTION.

124. ***Propagation velocity*** (= V) ***of Asama-yama detonation between Yuno-taira and Tokyo.*** In the two explosions of Aug. 12th, 1913, at 11.20 p.m. (§§ 62 and 117) and of May 5th, 1914, at 0.33 a.m. (§§ 63 and 117), the times of occurrence of the barometric disturbance at Yuno-taira and of the "sound shock" in Tokyo have been accurately determined; the barometric disturbance and the "sound shock" being identical with the actual detonation (Chapters XII and XIII). We have:—

Explosion.	Commencement of Barometric Disturbance at Yuno-taira (from Barograph, § 116).	Commencement of "Sound Shock" in Tokyo.	Time Difference between Yuno-taira and Tokyo.
	h m s	h m s	m s
(i) Aug. 12th, 1913.	11 20 40.4 p.m.	11 27 07.0 p.m.(1)	6 26.6
(ii) May 5th, 1914.	0 33 10.3 a.m.	0 39 38.0 a.m.(2)	6 27.7

(1) From the tromometer record at the Seismological Institute.

(2) From the direct time observation by the present author at his house.

Thus the time intervals taken by the sound waves in travelling the space between the observatory on the volcano and the city of Tokyo were on the two occassions respectively $6^{m}\ 26.6^{s}$ and $6^{m}\ 27.7^{s}$. For (i) the difference of the radial (sound path) distances of the Yuno-taira observatory and the Seismological Institute is $135.40^{km}-2.38^{km}=133.02^{km}$; the propagation velocity of the detonation being 344.1 m/sec., as follows:—

$$V=\frac{133.02^{km}}{6^{m}\ 26.6^{s}}=344.1\ \text{m/sec.}$$

For (ii), the difference of the radial distances between Yuno-taira and the author's house, is $132.08^{km}-2.38^{km}=129.70^{km}$; the propagation velocity being 334.5 m/sec.:

$$V=\frac{129.70^{km}}{6^{m}\ 27.7^{s}}=334.5\ \text{m/sec.}$$

Again, for (i), the air temperature at the different places along or near the sound path, namely, at Maebashi, Kumagai, Yokohama, and Tokyo, was between 19.6°C and 28.4°C with the average of 25°C; while that for (ii) was from 7.5° to 13.1°C., with the average of 10.6°C. The values of the ordinary sound propagation corresponding to these two mean *surface* air temperatures are 347.6 and 338.8 m/sec., being respectively 3.5 and

4.3 m/s too large than the values actually found, as ought to be, the air temperature at the surface being probably about 6°C higher than the mean value along the actual sound path.

125. ***Time difference between arrivals of earthquake and sound waves.*** For the strong Asama-yama explosions observed in 1913 at the Asama Pasture Ground and Ashino-taira, the time differences between the arrivals of the sound shock and the earthquake motion were as follows:—

Explosion. (1913).		Asama Pasture Ground.		Ashino-taira.	
		(i) Sound-{Eqke Comm't}	(ii) Sound-Explosion.	(i) Sound-{Eqke Comm't}	(ii) Sound-Explosion.
Sept. 21st	(L)	17.3 sec.	16.1 sec.	14.0 sec.	12.5 sec.
	(T)	17.2	—	—	—
Oct. 15th	(L)	—	—	14.4	12.8
	(T)	17.5	—	14.3	—
„ 17th	(L)	17.2	16.0	—	—
	(T)	17.0	—	—	—
„ 22nd	(L)	—	16.5	—	—
	(T)	—	—	—	—
Mean.		**17.2**	**16.2**	**14.2**	**12.6**

In the above table, (i) relates to the retardation time of the sound waves with respect to the commencement of the earthquake motion, and (ii) to that with respect to the moment of the explosion, namely, the end of the 1st displacement of the "initial vibration." The air temperature at the observing places at or about the time of the explosion on the 4 occasions taken into consideration varied from 5° to 16°C, giving the mean of about 12°C and 13°C respectively for the Asama Pasture Ground and for Ashino-taira. Again, for the 10 explosions observed at Yuno-taira, for which the time differences in question have been examined in § 121, the air temperature at the observatory varied from 7.5° to 17.4° C, giving the mean value of 12° C. The mean air temperature corresponding to the sound paths between the different observing stations and the Asama-yama crater, which must be a few degrees lower than the values above obtained, may be assumed, in round number, and probably without an appreciable error, to be 10° C. We have, then, for this latter mean air temperature, the following general results :—

(For the air temperature of 10° C.)

Station.	(i) Time Difference: Sound-Earthquake Commencement.	(ii) Time Difference: Sound-Explosion.	Approximate Length of Sound Path.
Yuno-taira.	7.3 sec.	5.8 sec.	2380 m.
Ashino-taira.	14.2	12.6	4990
Asama Pasture Ground.	17.2	16.2	6490

126. ***Propagation velocity of explosive seismic waves at neighbourhood of origin.*** The distances given in the last column of the table at the end of the foregoing § are the approximate lengths of the sound paths from the crater centre to the different observing places. The mean values of the interval (ii), which gives the time difference between the arrivals of the detonation and of the earthquake vibration corresponding to the moment of the explosion, were 5.8 sec., 12.6 sec., and 16.2 sec. respectively for Yuno-taira, Ashino-taira, and the Asama Pasture Ground, very nearly in proportion to the path lengths of 2380 m, 4990 m, and 6490 m, giving the following mean relations :—

For Yuno-taira: $$2380^{\mathrm{m}}\left(\frac{1}{V_{10^\circ}}-\frac{1}{v}\right)=5.8\text{ sec.}$$

For Ashino-taira: $$4990^{\mathrm{m}}\left(\frac{1}{V_{10^\circ}}-\frac{1}{v}\right)=12.6 \text{ sec.}$$

,, Asama Pasture Ground: $$6490^{\mathrm{m}}\left(\frac{1}{V_{10^\circ}}-\frac{1}{v}\right)=16.2 \text{ ,,}$$

in which v is the propagation velocity of the "initial vibration," and V_{10° that of the detonation, or sound shock, corresponding to the air temperature of 10°C. Now, as the velocity increase with the magnitude of the detonation is anyhow limited to the very vicinity of the explosion centre, and as, more especially, the explosive violence communicated to the atmospheric mass at the mountain top ought to be directed upwards, the sound velocity of the explosions between the crater and the lower places of Yuno-taira, Ashino-taira, and the Asama Pasture Ground, may probably be assumed without much error to have the ordinary value for the corresponding air temperature.

Putting then $V_{10^\circ}=338$ m/sec. in the above equations, we obtain:

For Yuno-taira: $v = 2.0$ km/sec.

$$\left.\begin{array}{ll} \text{,, Ashino-taira:} & v = 2.32 \\ \text{,, Asama Pasture Ground:} & v = 2.17 \end{array}\right\}\overset{\text{Mean.}}{2.24} \text{ km/sec.}$$

Thus the propagation velocity of the "initial vibration," or the vibration generated at the moment of the explosion, is about 2.0 km/sec. for Yuno-taira (radial distance=2.39 km), and about 2.2 km/sec. for Ashino-taira and the Asama Pasture Ground taken together (mean radial distance=5.7 km).

According to the approximate estimations in § 6, the initial velocity with which the lava fragments are projected from the crater seems to be some 150 m/sec. If this be also the impulsive velocity communicated to the air over the crater, then the propagation velocity of the detonation at the immediate vicinity of the origin of explosion may be some 500 m/sec.

127. ***Velocity of transverse vibration.*** Taking together the results of the observations of the Asama-yama explosions at Ashino-taira and the Asama Pasture Ground, the duration of the preliminary portion in the transverse component was on the average about 1.0 sec. longer than in the longitudinal. This may be regarded as denoting the retardation interval of the motion in the transverse corresponding to the " initial vibration " in the longitudinal component, and gives, for the two above named places, a transverse propagation velocity of about 1.6 km/sec., which is to the corresponding longitudinal velocity in the ratio of nearly 2 : 3.

128. ***Small quick vibrations.*** The small quick vibrations of T=about $\frac{1}{3}$ sec. begin to appear first some seconds after the earthquake commencement, apparently depending on the radial distances of the observing places, as follows :—

(Longitudinal Component.)

Place.	Time Interval between the Appearance of the Small Quick Vibrations and	
	Earthquake Commencement.	End of 1st Displacement of "Initial Vibration."
Yuno-taira.	2.9 sec.	1.6 sec.
Ashino-taira.	5.4	3.9
Asama-Pasture Ground.	7.2	4.9

Making use of the figures in the last column of the above table and of the propagation velocities of the " initial vibration " in the longitudinal component given in § 126, we get, for the small quick vibrations in question, the following results :—

	Velocity of Small Quick Vibration.
For Yuno-taira :	0.85 km/sec.
„ Ashino-taira :	0.82
„ Asama Pasture Ground.	0.83

The velocity thus comes out nearly constant for the three observing places, with the mean value of 0.83 km per sec. The small quick movements in question may be the secondary surface vibrations.

129. ***Propagation velocity of explosive vibrations between Asama-yama and Tokyo.*** According to § 116, the differences between the time of occurrence at the Yuno-taira observatory, and the moments of arrival at the Seismological Institute of the preliminary and the maximum phases, of the earthquake motion due to the Asama-yama eruptions are respectively 42.6 and 73.6 sec. As the horizontal radial distances of these two places are 2.3 and 135.4 km, the propagation velocities between Yuno-taira and Tokyo are:—

Preliminary Tremor ....$v_1 = 133.1 / 42.6 = 3.1$ km/sec.

End of Preliminary Tremor....$v_2 = 133.1 / 60.5 = 2.2$
(Duration = 18 sec.)

Maximum Phase..............$v_3 = 133.1 / 73.6 = 1.8$

The velocity (v_1) of the preliminary tremor is thus 3.1 km/sec., which is nearly equal to that of the surface propagation, or the 3rd phase of the principal portion, of the ordinary earthquake motion. It is likely that the vibrations resulting from the explosions at the crater of the Asama-yama, 2½ km in height, are propagated to Tokyo essentially along the surface ground.* It is desirable that this result should be further verified.

130. ***Propagation velocity of earthquakes.*** The strong earthquakes, which originate from under the Asama-yama itself or the neighbouring districts, must be more or less deep-seated, and consequently we find the propagation velocity of their vibrations greater than that of the shakings caused by the explosions themselves. The velocity of propagation has been calculated in the cases of the two special semi-destructive shocks in 1912, namely, the Asama-yama earthquake of July 16th and of the Ueda earthquake of Aug. 17th, from the instrumental records obtained at the Yuno-taira observatory, the Seismological Institute in Tokyo and the meteorological observatory of Osaka ($\varphi=34° 39' N$, $\lambda=135° 26' E$). The distances of the two latter places from the crater of the Asama-yama are respectively 135.4 and 341.3 km, and those from the origin of the Ueda earthquake, 156.3 and 323.1 km. The differences in the times of earthquake occurrence between Yuno-taira and Tokyo were 28 sec., and those between Tokyo and Osaka 30 and 32 sec. The durations of the preliminary tremor in Tokyo and Osaka were respectively 18.3 and 20.4 sec., and 43.0 and 49.3 sec.

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* Similar suggestion has been made in the *Bulletin*, Vol. VI, No. 1, § 39.

(i) *Asama-yama earthquake of July 16th*, 1912. As the duration of the preliminary tremor at the Yuno-taira observatory was very short, the radial distance of the latter may be assumed to be about 3 km. The following table gives the time of commencement and the duration of the preliminary tremor at the Yuno-taira observatory, the Seismological Institute (Tokyo), and the Osaka meteorological observatory.

Station.	Radial Distance.	Time of Eqke Occurrence.	Duration of Prel. Tremor.
Yuno-taira Obs.	3 km.	7.45.35 a.m.	Very short or 0 sec.
Seismol. Institute.	135.4	7.46.03	18.3
Osaka Met. Obs.	341.3	7.46.33	49.3

The values of the propagation velocity, v_1, of the first preliminary tremor between the different stations are found as follows :—

Between Yuno-taira and Tokyo....$v_1 = \dfrac{132.4^{km}}{28^{sec.}} = 4.7$ km/sec.

" Yuno-taira " Osaka....$v_1 = \dfrac{338.3}{58} = 5.8$

" Tokyo " Osaka....$v_1 = \dfrac{205.9}{30} = 6.9$

For the propagation velocity, v_3, of the vibration at the commencement of the principal portion, we have:—

Between Yuno-taira and Tokyo....$v_3 = \dfrac{132.4^{km}}{28+18.3^{sec.}} = 2.86$ km/sec.

" Yuno-taira " Osaka....$v_3 = \dfrac{338.3}{58+49.3} = 3.15$

" Tokyo " Osaka....$v_3 = \dfrac{205.9}{30+31.0} = 3.38$

(ii) *Ueda earthquake of Aug. 17th,* 1912. The time of occurrence and the duration of the preliminary tremor of this earthquake, whose origin was at $\varphi=36°\ 26'$N, $\lambda=138°\ 15'\ 35''$ E, or about 25 km to the N 77° W of the Asama-yama crater, at the Yunotaira observatory (Asama-yama), the Seismological Institute of Tokyo, and the meteorological observatory of Osaka, were as shown in the following table.

Station.	Radial Distance.	Time of Eqke Occurrence.	Duration of Prel. Tremor.
Yuno-taira.	23 km	$11^h\ 21^m\ 25^s$ pm.	4.2 sec.
Tokyo (Seism. Institute).	156.3	11 21 53	20.4
Osaka.	323.1	11 22 24.8	43.0

The values of the propagation velocity, v_1, of the first preliminary tremor between the different stations are found to be about 5 km/sec., as follows:—

$$\text{Between Yuno-taira and Tokyo} \ldots\ldots v_1 = \frac{133^{\text{km}}}{28^{\text{sec.}}} = 4.8 \text{ km/sec.}$$

$$\text{,, Yuno-taira ,, Osaka} \ldots\ldots v_1 = \frac{300^{\text{km}}}{60^{\text{sec.}}} = 5.0 \text{ ,,}$$

$$\text{,, Tokyo ,, Osaka} \ldots\ldots v_1 = \frac{167^{\text{km}}}{32^{\text{sec.}}} = 5.2 \text{ ,,}$$

For the calculation of the propagation velocity, v_3, of the vibration at the commencement of the principal portion, we have:

$$\text{Between Yuno-taira and Tokyo} \ldots\ldots v_3 = \frac{133^{\text{km}}}{28+16.2} = 3.01 \text{ km/sec.}$$

$$\text{,, Yuno-taira ,, Osaka} \ldots\ldots v_3 = \frac{300^{\text{km}}}{60+38.8} = 3.04 \text{ ,,}$$

$$\text{,, Tokyo ,, Osaka} \ldots\ldots v_3 = \frac{167^{\text{km}}}{32+22.6} = 3.06 \text{ ,,}$$

Summary. The results obtained above are collected in the following table :—

(Velocities v_1 and v_3 in km/sec.)

Radial Distance.	v_1 (Commencement of Earthquake).			v_3 (Commencement of Principal Portion).		
	Eqke i.	Eqke ii.	Mean.	Eqke i.	Eqke ii.	Mean.
Asama-yama to Tokyo.	4.7	4.8	4.7	2.86	3.01	2.94
Asama-yama to Osaka.	5.8	5.0	5.4	3.15	3.04	3.10
Tokyo to Osaka.	6.9	5.2	6.0	3.38	3.06	3.22

Thus the mean values of the velocity (v_1) of the preliminary tremor of the earthquakes were 4.7 and 5.4 km/sec. for the radial distances of about 135 and 341 km from the Asama-yama respectively to Tokyo and Osaka. The velocity calculated by the "difference method" between the two latter places was 6.0 km/sec. The velocity (v_3), which corresponds to the commencement of the principal portion, and which characterizes the surface propagation, did not much vary, being 2.9 and 3.1 km/sec. for the distances respectively to Tokyo and Osaka, and 3.2 km/sec. between the two latter places.

CHAPTER XV. CONDITION OF ASAMA-YAMA, 1912 TO 1914.

131. ***Strong Asama-yama earthquakes in relation to eruptions.*** The recent extraordinary activity of the Asama-yama may be considered to have began with the strong non-eruptive earthquake of May 26th, 1908. Yet the energetic explosions of the volcano took place first from Dec. 7th of the next year (1909), followed by several others in 1910 and 1911. After the strong explosion of Oct. 22nd, 1911, the eruptive activity was greatly reduced, there having been no important outburst of the Asama-yama during the summer of 1912. At the same time, however, the seismic activity of the volcano became very pronounced, and, amongst the others, the earthquake on July 16th (1912), at 7.45.35 a.m., was markedly strong, being, according to the tromometer observations in Tokyo, of the same magnitude with, and identical almost vibration for vibration to, the shock on May 26th, 1908. The period of the greatest explosive activity of the Asama-yama began with the outburst of May 16th, the next year (1913). From these circumstances, it seems that the opening of a period of great eruptive activity of the volcano is announced by strong seismic disturbances 10 months or 1½ years beforehand. Such an assumption is by no means unreasonable: for instance, the premonitary earthquake shocks of the Kirishima-yama explosion of Nov. 8th, 1913, had began already 6 months before the latter date. In other words, the explosions, which are themselves mere surface phenomena, must be the results of the long-continued and deep-seated underground stress accumulation, which may not be limited simply to the immediate vicinity of a particular volcano or to the extension of a single volcanic chain.

132. ***Condition of crater in summer of* 1912.** As mentioned in the *Bulletin*, Vol. VI, No. 1, the lava bottom of the Asama-yama crater was subject to elevation since many years, with the mean annual rate of about 4.3 m between 1887 and 1911; the actual depth measured at the NW part of the brim in June of the latter year being 120 m. This depth remained essentially unaltered on the whole till the summer of 1912, although there were evidently certain fluctuations of level and changes in form of the crater bottom attending the different strong eruptions which had happened before that year. In fact, the appearance of the bottom was constantly changing, being sometimes almost perfectly smooth, and at other times very rugged and broken into a number of high ridges. As will be seen from Fig. 1, the bottom of the crater was on July 2nd, 1912, folded into a series of beautiful regular concentric rings, with a deep depression or shaft some 20 m or so in diameter situated nearly at the centre, from which the smokes were powerfully ejected. According to the photographs and sketches taken by Professors S. Nakamura and N. Yamazaki in Sept. 1909, such had also been the condition of the crater bottom after the strong explosion of May 31st, 1909. The formation of the rings above referred to was due, not to anything like a wave motion of the fluid lava, but to the successive concentric depression or downward dislocations of the lava crust at the bottom, which had been after a previous strong eruption thrown into a plane or slightly convex surface.* When viewed on Aug.

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* In this way a terrace of lava is formed along the inner circumference of the crater, as was exhibited in a most remarkable manner during the recent activity of the O-shima volcano.

23rd (1912), the lava rings in the northern half of the crater bottom were broken away and substituted by a number of small vents formed on an irregular field of apparently sandy scoriæ. (See Figs. 72 and 74.)

133. ***Eruptions of Oct. 2nd and Dec. 13th-14th, 1912.*** On Oct. 1st, 1912, the condition of the crater bottom has been ascertained by Mr. T. Kato to be nearly in the same condition as on Aug. 23rd in the previous summer. The very next day, on Oct. 2nd, took place the special outbursts which consisted in the occurrence of several hundred small non-detonative eruptions, extending over a time interval of more than 9 hours. (See § 71.) As the result of this long-continued activity, the lava layer at the crater bottom was converted into one smooth convex field and raised through an extraordinary distance of about 30 m. (See Fig. 73.) The upheaval of the lava mass was much increased by the stronger outbursts on Dec. 13th and 14th of the same year, which lasted about 31 hours. One week after, namely, on Dec. 21st, the author, who ascended the mountain with Mr. Kanbayashi, of the Nagano meteorological observatory, found the bottom elevated practically to the brim, the steep cliff inside walls of the crater having been entirely buried by the lava, which was, should any further outburst of similar nature take place, ready to flow out northwards, the crater wall being lowest in that direction. The possible descent of lava streams was, however, no cause of much uneasiness, as these would have no high velocity of progress, and be, further, brought to stoppage already at the mountain base, being thus unable to reach, and cause damage in, the villages themselves. (See Fig. 15). The event of more dreadful nature was in the downrush of a burning "mud stream" or "volcanic avalanch." As described in the *Bulletin*, Vol. VI, the enormous

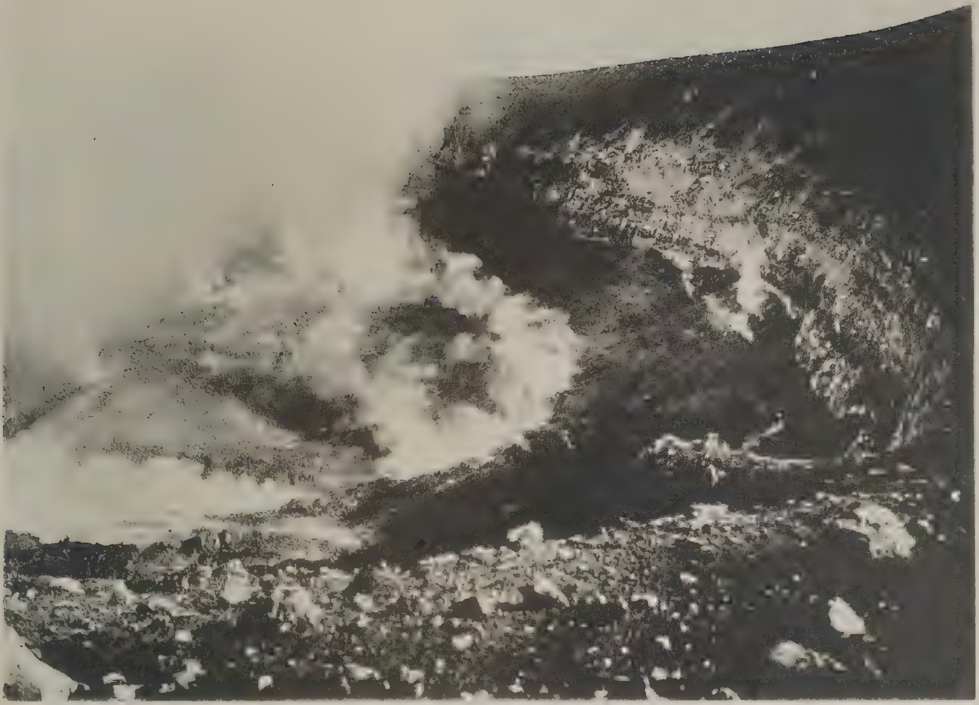

Fig. 72. Crater of Asama-yama, seen from SSW, on Aug. 23rd, 1912. (F. Omori, phot.)

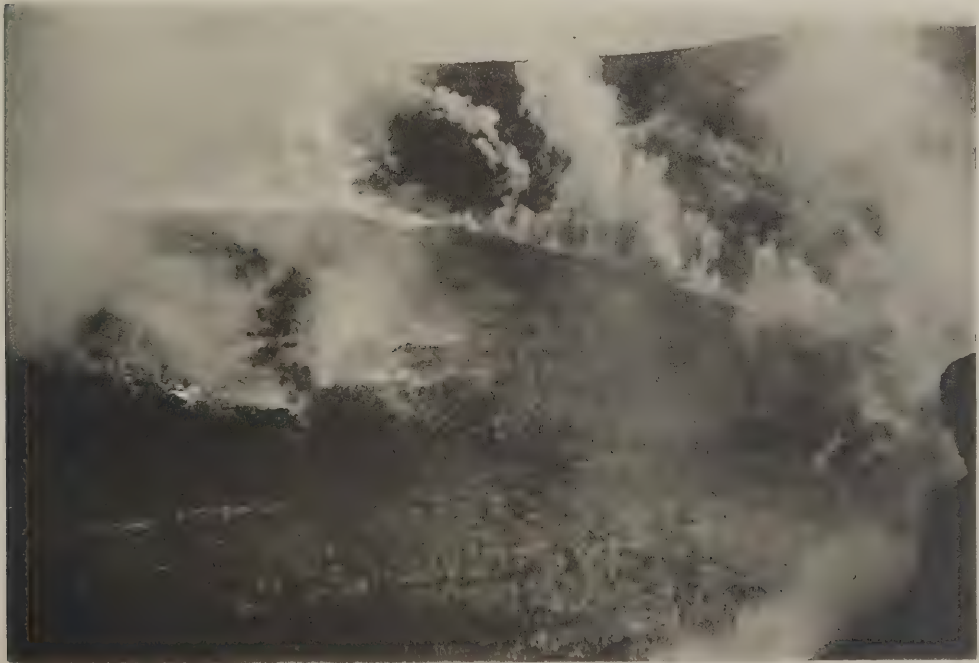

Fig. 73. Crater of Asama-yama, seen from SSW, on Oct. 14th, 1912, showing a remarkable elevation of the bottom, consequent to the eruption on the 2nd of the same month. (T. Kato, phot.)

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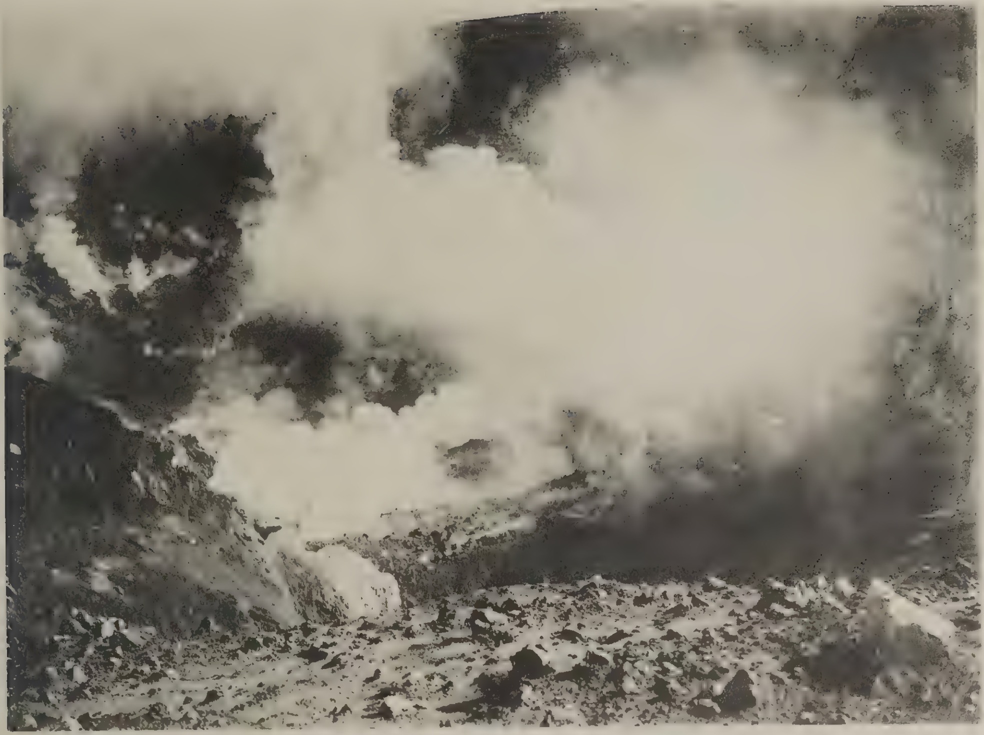

Fig. 74. Crater of Asama-yama, seen from SSW, on Aug. 23rd, 1912. (F. Omori, phot.)

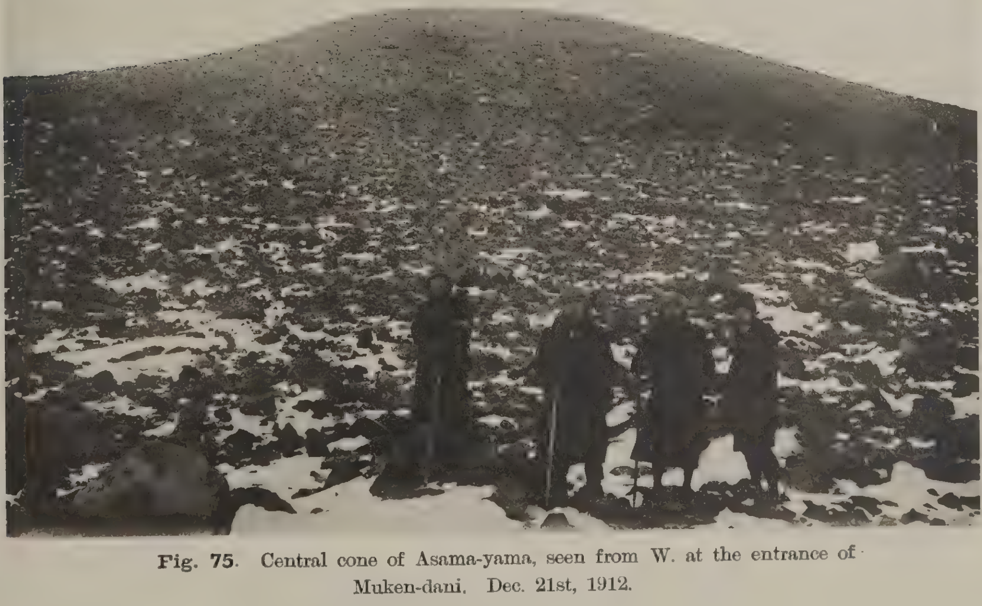

Fig. 75. Central cone of Asama-yama, seen from W. at the entrance of Muken-dani. Dec. 21st, 1912.

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damage on the occasion of the great Temmei (1783) catastrophe of the Asama-yama was due to the tremendous " volcanic avalanches," which precipitated themselves northwards into the upper valley of the river Agatsuma-gawa, a tributary of the Tone-gawa. Similar events occurred evidently also in the older times ; the whole southern slope of the Asama-yama between Kutsukake and Miyota being covered by the product of the former volcanic avalanches, which took place probably on the occasion of the eruptions in Aug. to Oct., 1108, when the volcanic stones, sands, and ashes are said to have buried the cultivated fields for about 18 miles.*

The occurrence of new volcanic avalanches, at least, of those of any large magnitude, seemed, however, improbable. Thus, before the great Temmei eruptions the Asama-yama had been very quiet for about 50 years and the crater had been entirely filled up, the rocks and earth at the mountain top, by exploding which the deep central vent was opened up, having probably furnished the material of the fearful volcanic avalanches ; whereas the present conditions of the Asama-yama, which has maintained activity since 1908 are different from those for 1783, there having existed the actual crater from the commencement, with no obstacle to the free overflowing of the inside lava mass. The above was the reasoning, by which I tried to remove the panic of the people of the villages and towns at the mountain bases, and, as a matter of fact, the conditions of the crater have changed since then considerably for the better, as mentioned in § 135.

The half pumiceous light-brownish lava masses, projected out on the occasion of the eruptions of Dec. 13th-14th (1912) was considerable in amount and covered the whole mountain top* ; having entirely buried the large radial cracks at the west side. Among the numerous bread-crust bombs, found on this occasion at the Muken-dani and around the crater, there were several of light bluish-white colour, which contained pieces of cordierite (Fig. 11).

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* Along the railway and also from among the village grounds of Kariyado and Furujiku, situated between the towns of Oiwake and Miyota, recently were discovered at many places " natural charcoal," or trees, apparently *Quercus glandulifera*, converted actually into charcoal in consequence of having been covered up by the hot materials of the volcanic avalanches in the above mentioned remote epoch. The charred trees were so far generally found at the depth of 1 or 2 metres.

134. *Strong explosions in* 1913. The year 1913 may be regarded as forming the most explosive period of the Asama-yama since its great outbursts in 1783 ; the strong explosions, which were frequent just in the months of May, June, July, and August, greatly terrifying the people at Karuizawa, a favourite summer resort for the fashionable Japanese and the foreign residents. The author was at the time asked many questions regarding the supposed inclination of the crater shaft toward Karuizawa, the best things to be done in the case of poisonous gases spreading over the latter place, etc. Finally, on July 25th the foreign visitors in Karuizawa sent to me, through Mr. R. A. Coates, a telegram stating their resolution to leave the place, if there be any danger from the Asama-yama eruptions. The following is the note, which I wrote in answer under the date of July 26th, assuring them that there was no cause for panic :—" The Asama-yama explosions, occurring at present once every 5 or 6 days, throw out hot lava fragments, which reached the observatory ground already on three occasions. Consequently, the seismological observations have, in a near feature, possibly after a few weeks, to be made at a lower station. The furthest distance of the stone *projection* is, however, only about 1½ miles, so that even in a very violent explosion the lava fragments would never be thrown to Karuizawa and other villages at the mountain base. Thus, there is.... no danger to life at Karuizawa in connection with the Asama-yama explosions. Neither there is any necessity for quitting the place, so long as these occur singly, however violent. Should the eruptions continue (i.e., occur one after the other at very close intervals, say, once every a few minutes,) for several consecutive days, hot ashes, sands, and pumice might commence to fall at Karuizawa and then it would be prudent for the people to leave the place gradually." The volcanic gases proved very injurious to plants, and by degrees the extensive forests of *Pinus densiflora*, especially those in the different radial valleys, were caused to die. On the Rokuriga-hara, at the N. base of the Asama-yama, even the comparatively well-resisting *Larix leptolepis* began to be killed since 1912.

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* Fig. 75 is a picture of the Asama-yama top taken from the Muken-dani at about 10 a.m., on Dec. 21st. The mountain slope was thinly covered with snow (maximum depth = 0.5 m) and the air temperature at the crater rim was only –1°C, due no doubt to the warming effect of the hot lava masses in the crater.

According to the report of Mr. J. Nishizawa, Director of the Nagano meteorological observatory, who ascended the mountain on April 11th, 1913, the crater bottom, elevated at the end of 1912, seems to have suffered some change and been depressed such that the top of a small lava mound, which came into existence at the centre, was some 10 m below the lowest, or N side, point of the surrounding wall. During the following summer months, the ascent was too risky on account of the frequent violent explosions, which projected hard lava blocks and bombs to the unusually great radial distances; the effects, not merely of the shallowness of the crater, but principally of the approach of the centre of volcanic activity to a certain depth most favourable for the projection of lava fragments. (§ 6.) Apart from the explosions, however, the earthquake effects accompanying the non-detonative eruptions of Nov. 6th (1913) at 1.21 and at 7.35 p.m., gave unusually large records in Tokyo, the motion in the latter case having lasted about 23 min. Thus, it being desirable to ascertain the condition of the crater, I ascended the mountain on Nov. 19th, in company with my assistant, Mr. H. Kurosaka, and found, rather contrary to my expectation, the crater bottom markedly depressed, to a depth of some 30 fathoms below the brim (at the SW part); the central well-like hole, from which the smokes were powerfully emitted, being surrounded by a long hilly arc, which was probably the remnant of the "lava rings" similar to those before mentioned. The upper part of the mountain was covered by the massive lava pieces of dark colours, which completely hid the lighter materials ejected out by the eruptions at the end of the preceding year; the new maximum block, found at the Muken-dani, being about 3 m in length. In spite of the extraordinary explosive activity, then, the crater bottom was, in 1913, on the way of being again depressed back. Further, a marked feature of the Asama-yama activity in the same year was the extremely small number of the non-eruptive earthquakes originating from the volcano.

135. ***Condition of Asama-yama in* 1914.** According to the accounts of Dr. I. Ishiguro and Professor A. Tanakadate, Mr. J. Nishizawa, and Mr. H. Kurosaka, who ascended the volcano this year respectively on May 27th, June 21st, and July 26th, the depression of the crater bottom is steadily continuing; the depth at the east side being, in the estimation of Mr. Nishizawa, being nearly 80 m. Coupled to this fact, both the seismic and the eruptive activities of the Asama-yama have suffered a considerable reduction in the course of the present year so far. Thus, in the tromometer registers at Yuno-taira, there were, between May 1st and July 17th, (1914), altogether 13 non-eruptive volcanic shocks and 19 eruptions, of the latter only that on May 5th being strongly explosive. The smallness of the activity of the

Asama-yama in the time interval under consideration will be realized, when we remember of the large number of the violent explosions in 1913, or of the Yuno-taira tromometer registrations, which amounted to 378 non-eruptive volcanic shocks and 577 eruptions in 1911, between June and October, and to 687 non-eruptive shocks and 1,111 eruptions in 1912, between May and October. Turning our attention at large to the recent volcanic manifestations in the different parts of Japan, we notice that, the Yake-dake, the O-shima, the Kirishima-yama, and the Sakura-jima, which made marked eruptions after (in the case of the Yake-dake, before) the commencement in 1908 of the activity of the Asama-yama, have all now already been brought to end, and, from various circumstances, the Asama-yama itself is to be supposed also to be on the way of settling back to its ordinary condition.

July 1914. Tokyo.

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THE ERUPTIONS AND EARTHQUAKES OF THE ASAMA-YAMA. V.

[Lists of the Volcanic Disturbances instrumentally registered at the Asama-yama Seismological Stations, 1913 to 1916.]

By

F. OMORI, Sc.D.,

Member of the Imperial Earthquake Investigation Committee.

The tromometer observations at the Yuno-taira (Asama-yama) seismological station has been carried on during the six warmer months, May to October, every year since 1911 ; and the lists in the following pages form the continuation of those contained in Volume VI, No. 2, of the *Bulletin*, giving for the Asama-yama disturbances, during the four years 1913 to 1916, the date, the time of occurrence, the duration of the preliminary tremor, the maximum double amplitude,* and the total duration of motion. The principal instruments of observation were the same as those used in the previous years, namely, a horizontal pendulum tromometer and a two-component portable horizontal tremor-recorder ; the record being taken on the smoked paper whose rate of displacement was usually 1 to 2 cm. per minute, but on several occasions was increased up to 5 to 7 cm. per minute. The orientation of the tremor-recorder, of 100 times magnification, was such that the two pendulums registered respectively the movements parallel and normal to the line joining the place of observation with the centre of the volcano, or the apparent longitudinal and the apparent transverse vibrations assumed to proceed from under the crater. The tromometer, of 200 times magnification, was set up so as to record the former component motion.

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* For a greater portion of the 1913 observations (Tables Ib and Ic), the statement of the maximum motion of the eruptive shakings is restricted to the longitudinal component as indicated by the tromometer, on account of the great number of the disturbances in question during that year.

As before the Asama-yama disturbances are divided into two distinct classes, namely:—A-type motion, or the volcanic earthquakes not directly accompanied by an outburst; and B-type motion, or the shaking of the ground caused by an eruption. The A-type earthquakes consisted of quick vibrations and were generally very short in duration; while the B-type shakings were composed of slow gentle movements and comparatively long in duration. The numbers of the disturbances belonging to these two classes are as follows:—

Year (May–Oct.)	(A): Earthquakes.*			(B): Eruptions.			Total
	Sensible.	Unfelt.	Sum.	Strong Explosions.	Small Outbursts.	Sum.	Sum.
1913	6	28	34	25	7101	7126	7160
1914	11	37	48	1	30	31	79
1915	44	65	109	0	0	0	109
1916	64	165	229	0	2	2	231

It will be observed that the eruptive energy was greatest in the year 1913, the number of the outbursts amounting to 7126, of which 25 were strongly explosive. In June, July, and August of that year the violence of the eruptions was such that the lava fragments projected from the crater reached, or even got beyond, the ground of the Yuno-taira observatory. Consequently the observation had during the subsequent two months to be carried on temporarily at the lower and safer locality of Ashino-taira. After May 5th, 1914, there has been no strong outburst of the Asama-yama. The A-type shakings or earthquakes, which were very few in 1913, much increased in frequency and intensity in the two years, 1915 and 1916, when the Asama-yama made practically no eruptive manifestation.

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* Earthquake shocks whose origins were appreciably distant from the Asama-yama are not included in the tables.

The position relative to the centre of the crater mouth of the two seismological stations of Yuno-taira and Ashino-taira, both situated on the Komoro, or W. S. W., slope of the volcano, are as follows :—

	Height Difference.	Radial Distance.
Yuno-taira :	580 m. ;	2300 m.
Ashino-taira :	1130 ;	4850

According to the latest (1912) Military Survey map of the Asama-yama district, the height of the mountain top is 2542 m.

As formerly I must state my obligations to Messrs. J. Nishizawa, J. Kambayashi, J. Tamra, T. Ushiyama, M. Kawazoe, and K. Yoda, of the Nagano Meteorological Observatory, and to Messrs. T. Kato, T. Toyoda, and H. Krosaka, of the Seismological Institute, who took part in the Asama-yama observations with continued zeal; the three last-named gentlemen having also carried on the extremely laborious work of calculating the elements of motion of the numerous disturbances.

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TABLE I, A. LIST OF THE ASAMA VOLCANIC DISTURBANCES INSTRUMENTALLY REGISTERED AT THE ASAMA-YAMA (YUNO-TAIRA) SEISMOLOGICAL OBSERVATORY.
MAY 1ST TO JUNE 20TH, 1913.

[A]....VOLCANIC EARTHQUAKE NOT ACCOMPANIED BY ERUPTION.
[B]....EARTH-SHAKING CAUSED BY VOLCANIC ERUPTION.

(2a denotes the maximum range of motion, in micron.)

Date (1913).	Time of Occurrence.	Duration of Preliminary Tremor.	Max. 2a.		Total Duration.	Character.
			Longitudinal.	Transverse.		
MAY		sec.	μ	μ	sec.	
4	11 21 11 p.m.	—	4	—	—	B
7	6 51 27 ,,	1.1	7	—	—	A
8	3 51 53 a.m.	—	10	—	60	B
9	0 34 11 ,,	0.9	9	—	3	A
11	4 18 44 ,,	—	2	—	—	B
,,	0 09 53 p.m.	2.6	3	—	17	A
12	4 43 52 a.m.	0	8	—	—	,,
,,	4 43 54 ,,	—	7	—	—	,,
13	3 40 29 ,,	0	7	—	4	,,
,,	9 41 01 ,,	2.1	—	—	17	B
,,	10 27 45 ,,	—	—	—	—	A
,,	10 29 25 ,,	—	—	—	—	B
,,	10 29 54 ,,	—	—	—	—	,,
,,	10 30 15 ,,	—	—	—	—	,,
,,	10 31 36 ,,	—	—	—	—	,,
,,	10 35 00 ,,	—	—	—	—	,,
,,	10 39 48 ,,	—	—	—	—	,,
,,	11 38 18 ,,	—	—	—	—	,,
,,	1 08 22 p.m.	—	—	—	—	,,
,,	10 46 03 ,,	0	5	—	—	A
14	5 50 35 ,,	0	3	2	13	,,
16	4 41 00 ,,	0.26	102	100	95	B (Strong explosion.)
18	2 44 33 ,,	0	29	13	11	A
,,	8 36 35 ,,	0	8	10	7	,,
20	1 27 17 a.m.	—	1	—	33	B
,,	8 49 25 p.m.	1.8	9	32	9	A
21	3 42 52 a.m.	0	12	—	3	,,
25	3 04 30 p.m.	—	1	1	40	B
,,	3 05 10 ,,	—	2	—	41	,,
27	5 22 57 a.m.	0	62	55	73	B (Strong explosion.)

Date (1913).	Time of Occurrence.	Duration of Preliminary Tremor.	Max. 2a.		Total Duration.	Character.
			Longitudinal.	Transverse.		
MAY		sec.	μ	μ	sec.	
28	8 07 13 p.m.	—	1	1	64	B
29	10 44 12 a.m.	0.16	98	76	90	B (Strong explosion.)
30	6 56 07 p.m.	—	1	2	137	,,
JUNE 2	0 10 45 a.m.	—	1	—	30	,,
,,	0 20 21 ,,	—	1	—	—	,,
,,	0 04 48 ,,	2.5	2	2	35	,,
5	4 53 28 ,,	0	32	18	14	A (Sensible shock.)
7	11 00 22 ,,	0	12	14	3	,,
,,	11 05 57 ,,	0	22	42	7	,,
,,	11 25 59 ,,	0	8	—	2	,,
,,	11 26 02 ,,	0	16	8	3	,,
13	10 39 11 ,,	0.6	59	35	12	A (Sensible shock.)
,,	7 17 21 p.m.	0.6	9	—	4	,,
,,	11 01 16 ,,	—	20	13	72	B (Strong explosion.)
14	4 15 49 a.m.	4.2	2	2	75	,,
16	9 13 44 p.m.	0	94	66	55	A (Sensible shock.)
17	10 47 41 ,,	0.37	110	93	120	B (Very strong explosion.)
18	6 21 03 a.m.	1.5	30	23	113	B (Strong explosion.)
20	4 06 47 ,,	—	25	20	94	B (Strong explosion.)

TABLE I, B. LIST OF THE ASAMA VOLCANIC OUTBURSTS INSTRUMENTALLY REGISTERED AT THE ASAMA-YAMA (YUNO-TAIRA) SEISMOLOGICAL OBSERVATORY.

JUNE 21ST TO AUG. 31ST, 1913.

ALL THE DISTURBANCES CONTAINED IN THIS TABLE WERE OF THE [B] TYPE, BEING THE EARTH-SHAKINGS CAUSED BY VOLCANIC OUTBURSTS.

(2a denotes the maximum longitudinal motion, in micron.)

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
JUNE 21	sec.	μ	sec.	**JUNE 21**	sec.	μ	sec.
2 07 32 p.m.	1.4	1	16	6 50 31 p.m.	—	1	52
2 11 01 ,,	—	1	15	7 12 47 ,,	—	1	45
2 11 50 ,,	—	1	45	7 26 05 ,,	—	1	33
2 30 02 ,,	—	2	23	7 31 38 ,,	—	1	27
2 53 19 ,,	3.7	1	28	7 35 26 ,,	2.5	1	28
2 58 11 ,,	—	1	36	7 37 57 ,,	2.0	1	31
3 19 07 ,,	3.2	2	32	7 42 58 ,,	2.6	1	40
3 46 03 ,,	1.9	1	23	7 44 33 ,,	1.3	1	18
3 55 21 ,,	—	1	30	7 45 17 ,,	—	1	34
4 11 23 ,,	2.1	2	27	7 52 43 ,,	—	2	17
4 11 56 ,,	—	1	28	7 58 36 ,,	1.1	1	22
4 40 33 ,,	—	1	—	8 02 25 ,,	3.4	1	34
4 41 05 ,,	—	1	56	8 06 57 ,,	3.1	1	36
4 44 58 ,,	—	1	—	8 14 58 ,,	2.2	2	—
4 45 30 ,,	—	1	—	8 15 30 ,,	—	1	36
4 45 50 ,,	—	1	56	8 19 35 ,,	2.4	1	24
4 48 38 ,,	2.3	1	35	8 20 59 ,,	2.4	3	46
4 56 07 ,,	—	1	27	8 22 53 ,,	2.0	1	—
4 58 55 ,,	—	1	—	8 23 08 ,,	2.0	1	29
4 59 10 ,,	2.0	1	33	8 23 59 ,,	—	1	58
5 04 37 ,,	—	1	25	8 28 55 ,,	—	1	24
5 05 14 ,,	—	1	—	8 29 41 ,,	2.0	1	27
5 05 34 ,,	—	1	50	8 31 51 ,,	—	1	28
5 08 11 ,,	2.5	1	30	8 33 35 ,,	2.1	1	24
5 11 04 ,,	2.6	1	39	8 35 02 ,,	3.0	1	32
5 12 30 ,,	—	1	46	8 36 29 ,,	—	1	56
5 38 31 ,,	—	1	40	8 37 54 ,,	—	1	—
6 18 04 ,,	—	1	29	8 38 06 ,,	—	1	25
6 38 20 ,,	—	1	31	8 42 39 ,,	—	1	40
6 49 59 ,,	—	1	16	8 44 24 ,,	—	1	16

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
JUNE 21	sec.	μ	sec.	**JUNE 21**	sec.	μ	sec.
8 45 13 p.m.	1.7	1	17	9 48 11 p.m.	—	1	20
8 46 56 ,,	—	1	20	9 48 38 ,,	—	1	14
8 47 22 ,,	—	1	16	9 50 45 ,,	—	2	45
8 49 33 ,,	—	1	24	9 52 05 ,,	—	1	—
8 51 18 ,,	1.6	1	39	9 52 26 ,,	2.0	1	31
8 54 41 ,,	—	1	21	9 56 15 ,,	—	1	17
8 55 27 ,,	2.2	1	28	10 00 47 ,,	—	1	26
8 56 28 ,,	2.0	1	27	10 03 41 ,,	—	1	24
8 57 28 ,,	1.4	1	—	10 08 38 ,,	—	1	23
8 57 46 ,,	2.4	1	26	10 17 31 ,,	1.9	1	23
8 58 55 ,,	2.0	1	18	10 22 05 ,,	—	1	25
8 59 21 ,,	2.0	1	28	10 24 05 ,,	2.4	1	31
9 01 31 ,,	—	1	26	10 25 02 ,,	2.1	1	24
9 09 23 ,,	3.1	1	21	10 25 55 ,,	—	1	15
9 11 36 ,,	1.1	1	29	10 29 53 ,,	—	1	29
9 12 31 ,,	1.6	1	26	10 30 38 ,,	1.7	1	21
9 13 15 ,,	1.5	1	35	10 33 51 ,,	1.3	1	20
9 14 07 ,,	—	1	39	10 36 17 ,,	1.3	2	31
9 15 26 ,,	2.0	1	43	10 39 59 ,,	1.4	1	30
9 18 47 ,,	—	1	29	10 42 18 ,,	—	1	16
9 19 46 ,,	2.8	1	25	10 42 54 ,,	1.0	1	27
9 21 04 ,,	1.8	1	22	10 43 31 ,,	—	1	32
9 21 31 ,,	2.2	1	18	10 45 30 ,,	1.0	1	31
9 21 53 ,,	—	1	29	10 47 50 ,,	1.0	1	25
9 22 54 ,,	—	1	14	10 48 30 ,,	—	1	16
9 27 36 ,,	1.6	2	40	10 49 50 ,,	—	1	22
9 30 06 ,,	—	1	—	10 50 34 ,,	—	1	34
9 30 21 ,,	—	1	37	10 51 11 ,,	—	1	21
9 32 15 ,,	—	1	14	10 51 44 ,,	—	1	16
9 33 11 ,,	—	1	—	10 52 03 ,,	—	1	17
9 33 33 ,,	2.3	1	35	10 53 28 ,,	—	1	21
9 37 42 ,,	—	1	28	10 54 32 ,,	—	1	50
9 38 18 ,,	2.3	1	26	10 56 18 ,,	—	1	29
9 38 46 ,,	—	1	17	10 59 21 ,,	—	1	13
9 41 38 ,,	2.8	1	—	11 02 18 ,,	—	1	17
9 41 52 ,,	—	1	34	11 07 24 ,,	—	1	24
9 42 50 ,,	—	1	29	11 07 58 ,,	—	1	20
9 45 04 ,,	—	1	—	11 11 26 ,,	1.3	1	39
9 45 41 ,,	—	1	24	11 12 31 ,,	—	1	28
9 47 48 ,,	—	1	22	11 13 05 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
JUNE 21	sec.	μ	sec.	**JUNE 22**	sec.	μ	sec.
11 13 26 p.m.	—	1	25	0 27 00 a.m.	1.7	1	28
11 15 02 „	—	1	19	0 28 15 „	—	1	19
11 15 45 „	—	2	25	0 29 05 „	—	1	24
11 16 15 „	—	1	20	0 31 41 „	—	1	24
11 20 21 „	—	1	44	0 39 52 „	—	1	29
11 22 26 „	1.1	2	37	0 42 22 „	—	1	33
11 23 08 „	—	1	14	0 43 21 „	1.6	1	33
11 23 27 „	—	1	24	0 52 08 „	—	1	35
11 23 51 „	—	2	—	0 54 19 „	—	1	25
11 24 27 „	—	1	25	0 58 34 „	—	1	18
11 26 30 „	0.6	3	—	1 01 20 „	—	1	19
11 26 58 „	—	1	25	1 13 07 „	—	1	26
11 28 59 „	—	1	25	1 14 53 „	—	1	20
11 30 31 „	—	1	31	1 27 31 „	1.3	1	15
11 32 27 „	—	1	20	1 31 43 „	—	1	17
11 32 55 „	—	1	43	1 45 30 „	1.3	1	23
11 34 01 „	—	1	25	1 56 25 „	—	1	14
11 35 45 „	—	1	15	2 28 25 „	—	1	15
11 38 07 „	—	1	26	2 32 17 „	—	1	19
11 40 18 „	1.1	1	19	2 32 41 „	—	1	17
11 41 47 „	—	1	26	2 39 34 „	—	1	30
11 45 49 „	—	1	15	3 25 25 „	—	1	22
11 46 09 „	—	1	18	3 28 46 „	—	1	25
11 49 57 „	—	1	41	3 29 49 „	—	1	28
11 51 07 „	—	1	18	3 38 04 „	1.2	1	18
11 52 29 „	—	1	13	4 04 38 „	1.2	1	23
11 53 00 „	—	1	19	**JUNE 23**			
11 56 25 „	—	1	20	0 42 37 p.m.	—	1	16
JUNE 22				1 06 35 „	—	1	17
0 02 26 a.m.	1.7	1	15	1 09 33 „	—	1	19
0 04 51 „	—	1	21	1 18 22 „	2.1	1	15
0 07 22 „	—	1	19	1 23 35 „	1.2	1	14
0 12 06 „	—	1	20	1 30 11 „	1.8	1	18
0 13 55 „	—	1	22	1 32 16 „	1.7	1	31
0 15 09 „	—	1	28	1 34 08 „	2.1	1	16
0 16 06 „	—	1	18	1 34 33 „	—	1	50
0 17 21 „	—	1	28	1 35 26 „	2.1	1	31
0 19 16 „	—	1	37	2 06 05 „	2.7	1	27
0 21 40 „	—	1	23	2 34 19 „	1.3	1	18
0 24 40 „	—	1	44	2 41 45 „	1.4	1	16
0 26 18 „	—	1	20	2 44 45 „	3.1	1	38

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
JUNE 23	sec.	μ	sec.	JUNE 23	sec.	μ	sec.
2 59 05 p.m.	2.9	1	24	6 01 07 p.m.	—	1	28
3 38 05 ,,	2.9	1	24	6 03 38 ,,	—	1	48
3 46 27 ,,	—	1	26	6 08 45 ,,	—	1	27
4 01 20 ,,	—	1	24	6 09 32 ,,	—	1	25
4 25 58 ,,	—	1	—	6 11 41 ,,	—	1	18
4 26 03 ,,	—	1	17	6 12 53 ,,	—	1	44
4 30 57 ,,	—	1	21	6 15 16 ,,	—	1	18
4 31 53 ,,	2.1	1	37	6 15 43 ,,	—	1	27
4 35 59 ,,	—	1	17	6 18 10 ,,	—	1	20
4 43 46 ,,	2.0	1	30	6 19 25 ,,	4.4	1	40
4 46 00 ,,	1.9	1	28	6 25 00 ,,	—	1	19
4 46 31 ,,	—	1	24	6 30 27 ,,	—	1	35
4 50 16 ,,	—	1	19	6 33 42 ,,	—	1	20
4 54 47 ,,	—	1	18	6 34 42 ,,	—	1	18
4 55 09 ,,	—	1	33	6 36 55 ,,	1.5	1	22
5 00 20 ,,	—	1	35	6 41 32 ,,	—	1	17
5 02 35 ,,	—	1	19	6 41 57 ,,	1.3	1	24
5 05 05 ,,	2.5	1	25	6 45 11 ,,	—	1	24
5 08 17 ,,	2.3	1	19	7 02 32 ,,	—	1	21
5 09 11 ,,	—	1	14	7 07 23 ,,	—	1	22
5 09 29 ,,	—	1	24	7 20 08 ,,	—	1	16
5 09 54 ,,	2.1	1	13	7 28 25 ,,	—	1	14
5 18 40 ,,	—	1	53	7 36 45 ,,	—	1	23
5 19 36 ,,	—	1	11	7 40 50 ,,	—	1	31
5 21 57 ,,	—	1	35	7 42 36 ,,	—	1	33
5 22 45 ,,	—	1	22	7 44 41 ,,	—	1	19
5 25 32 ,,	—	1	18	7 51 11 ,,	3.2	1	31
5 27 12 ,,	—	1	40	7 52 09 ,,	2.0	2	35
5 37 05 ,,	—	1	18	7 53 12 ,,	—	1	38
5 44 23 ,,	2.5	1	16	7 54 03 ,,	2.4	2	39
5 45 10 ,,	—	1	25	7 55 37 ,,	—	1	31
5 49 41 ,,	—	1	15	7 56 20 ,,	—	1	54
5 50 32 ,,	—	1	22	7 57 50 ,,	—	1	41
5 51 40 ,,	—	1	—	7 58 57 ,,	—	1	29
5 52 22 ,,	—	1	38	8 00 40 ,,	—	1	24
5 53 53 ,,	—	1	17	8 01 18 ,,	—	1	33
5 55 36 ,,	—	1	27	8 02 00 ,,	2.1	1	32
5 56 54 ,,	—	1	22	8 02 36 ,,	—	1	21
5 59 02 ,,	—	1	25	8 03 19 ,,	—	1	27
6 00 20 ,,	—	1	16	8 04 35 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
JUNE 23	sec.	μ	sec.	**JUNE 23**	sec.	μ	sec.
8 04 52 p.m.	—	1	—	9 13 32 p.m.	4.2	1	39
8 05 07 ,,	—	1	27	9 15 36 ,,	—	1	23
8 06 04 ,,	1.4	1	18	9 16 39 ,,	3.2	1	25
8 06 45 ,,	—	1	26	9 17 22 ,,	2.7	1	23
8 07 20 ,,	—	1	13	9 18 12 ,,	—	1	22
8 07 46 ,,	2.4	1	24	9 18 45 ,,	—	1	33
8 10 09 ,,	—	1	13	9 21 48 ,,	—	1	15
8 14 11 ,,	—	1	25	9 22 10 ,,	—	1	28
8 14 56 ,,	2.7	1	25	9 23 07 ,,	3.3	1	18
8 15 27 ,,	3.1	1	42	9 23 32 ,,	—	1	15
8 16 46 ,,	2.1	1	25	9 23 58 ,,	2.1	1	26
8 18 19 ,,	—	1	30	9 26 15 ,,	—	1	22
8 21 36 ,,	3.1	1	26	9 27 02 ,,	—	1	17
8 23 37 ,,	—	1	29	9 27 25 ,,	—	1	21
8 25 15 ,,	3.1	1	23	9 29 09 ,,	—	1	18
8 26 19 ,,	2.1	1	16	9 31 06 ,,	—	1	33
8 26 42 ,,	2.5	1	19	9 34 12 ,,	—	1	18
8 28 10 ,,	1.9	1	21	9 36 36 ,,	2.1	1	21
8 30 16 ,,	—	1	20	9 38 06 ,,	—	1	35
8 34 14 ,,	—	1	18	9 40 08 ,,	—	1	37
8 36 09 ,,	—	1	17	9 41 10 ,,	—	1	32
8 41 24 ,,	—	1	24	9 44 31 ,,	—	1	20
8 43 40 ,,	—	1	30	9 46 28 ,,	—	1	15
8 45 08 ,,	1.7	1	19	9 50 08 ,,	2.8	1	26
8 45 30 ,,	—	1	21	9 50 44 ,,	—	1	26
8 45 59 ,,	1.0	1	21	9 51 22 ,,	—	1	17
8 48 37 ,,	—	1	23	9 51 57 ,,	—	1	21
8 51 01 ,,	—	1	22	9 53 43 ,,	—	1	18
8 53 02 ,,	—	1	18	9 55 13 ,,	3.0	1	19
8 54 14 ,,	2.7	1	39	9 57 24 ,,	—	1	26
8 56 02 ,,	1.7	1	19	9 57 56 ,,	—	1	24
8 57 50 ,,	—	1	16	9 58 43 ,,	2.6	1	21
8 59 10 ,,	—	1	19	10 00 51 ,,	1.9	1	17
9 01 08 ,,	—	1	16	10 02 29 ,,	2.8	1	26
9 05 26 ,,	—	1	22	10 03 04 ,,	—	1	24
9 08 28 ,,	—	1	14	10 03 36 ,,	—	1	36
9 10 24 ,,	1.1	1	47	10 04 40 ,,	1.5	1	14
9 11 24 ,,	3.2	1	24	10 06 49 ,,	3.2	1	17
9 12 17 ,,	—	1	23	10 07 56 ,,	—	1	14
9 12 48 ,,	4.2	1	23	10 10 39 ,,	—	1	21

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
JUNE 23	sec.	μ	sec.
10 12 02 p.m.	—	1	18
10 12 25 ,,	—	1	30
10 13 12 ,,	—	1	23
10 16 44 ,,	—	1	29
10 17 33 ,,	—	1	20
10 18 26 ,,	3.7	1	18
10 23 37 ,,	—	1	13
10 24 04 ,,	—	1	26
10 25 35 ,,	3.9	1	25
10 27 07 ,,	—	1	20
10 27 32 ,,	2.9	1	20
10 29 40 ,,	—	1	20
10 30 22 ,,	—	1	25
10 31 23 ,,	—	1	31
10 32 04 ,,	2.5	1	31
10 33 29 ,,	—	1	16
10 34 41 ,,	—	1	23
10 36 03 ,,	—	1	28
10 36 59 ,,	3.9	1	26
10 37 47 ,,	—	1	30
10 42 27 ,,	—	1	17
10 42 51 ,,	—	1	24
10 43 24 ,,	—	1	33
10 45 37 ,,	—	1	24
10 47 23 ,,	—	1	20
10 48 16 ,,	2.8	1	21
10 49 49 ,,	—	1	16
10 51 46 ,,	—	1	18
10 55 16 ,,	—	1	20
10 57 22 ,,	3.3	1	18
10 58 40 ,,	—	1	17
10 59 20 ,,	—	1	20
11 03 28 ,,	—	1	22
11 04 51 ,,	3.2	1	37
11 07 49 ,,	—	1	16
JUNE 23	sec.	μ	sec.
11 11 04 p.m.	—	1	14
11 20 24 ,,	—	1	23
11 23 32 ,,	—	1	18
11 25 30 ,,	2.2	1	15
11 27 21 ,,	—	1	21
11 29 56 ,,	—	1	25
11 37 51 ,,	—	1	19
11 39 19 ,,	—	1	17
11 48 17 ,,	—	1	22
JUNE 24			
0 01 20 a.m.	—	1	18
0 09 08 ,,	—	1	13
0 22 44 ,,	2.6	1	15
0 24 40 ,,	—	1	19
1 07 43 ,,	—	1	15
1 31 06 ,,	—	1	25
1 38 04 ,,	—	1	20
3 32 15 ,,	—	1	19
11 37 34 ,, (1)	—	48	88
11 39 19 ,,	—	1	18
11 39 48 ,,	—	1	30
11 34 17 p.m.(2)	—	31	88
11 43 15 ,,	—	1	17
JUNE 26			
8 09 40 a.m.(3)	0.47	45	115
11 41 59 ,, (4)	0.37	93	150
JUNE 29			
10 19 14 a.m.	3.5	1	14
5 07 25 p.m.	2.4	1	21
9 33 58 ,, (5)	—	1	44
JULY 1			
0 17 01 p.m.(6)	2.3	48	150
0 21 27 ,,	—	1	13
0 21 45 ,,	—	1	18
0 45 58 ,,	—	1	20
0 48 14 ,,	—	2	14
0 52 02 ,,	—	1	21

(1) Strong explosion; the transverse max. $2a=41\mu$. (2) Strong explosion; the transverse max. $2a=30\mu$.
(3) Strong explosion; the transverse max. $2a.=30\mu$. (4) Strong explosion; the transverse max. $2a.=75\mu$.

(5) The transverse max. $2a=3\mu$, Two unfelt A-type disturbances, or earthquakes of the volcanic origin, occurred respectively at 11.20.52 p.m., on the 26th, and at 6.23.35 a.m., on the 28th, the elements of motion being as follows: —

1st eqke: Dur. Prel. Tremor=0.0 sec., Total Duration=10 sec., max. longit. $2a.=64\mu$.
2nd eqke: Dur. Prel. Tremor=0.6 sec., Total Duration=18 sec., max. longit. $2a.=38\mu$.

(6) An explosion accompanied by a loud dull booming sound: the transverse max. $2a.=44\mu$

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
JULY 1	sec.	μ	sec.
0 52 27 p.m.	—	2	16
0 56 01 ,,	—	2	25
0 56 36 ,,	—	2	20
0 57 53 ,,	—	1	18
1 00 45 ,,	—	2	24
1 02 48 ,,	—	3	24
JULY 2			
7 45 23 p.m.	2.3	1	14
7 45 39 ,,	2.3	2	12
8 10 26 ,,	—	1	18
JULY 5			
3 29 05 p.m.	—	1	16
3 41 11 ,,	—	1	23
3 42 10 ,,	1.6	1	31
3 42 46 ,,	—	1	14
3 46 47 ,,	—	1	16
3 54 49 ,,	—	1	26
3 56 41 ,,	—	1	15
4 00 48 ,,	1.2	1	14
4 03 32 ,,	—	1	36
4 09 48 ,,	—	1	15
4 11 24 ,,	—	1	17
4 12 01 ,,	—	1	17
4 15 11 ,,	—	1	19
4 22 58 ,,	—	1	24
4 24 14 ,,	2.7	3	28
4 28 12 ,,	—	1	19
4 32 09 ,,	2.3	1	18
4 33 41 ,,	—	1	17
4 34 34 ,,	—	1	14
4 40 37 ,,	—	1	21
4 42 04 ,,	—	1	21
4 42 46 ,,	—	1	12
4 45 52 ,,	—	1	40
4 49 33 ,,	2.8	2	20
4 53 26 ,,	—	1	36
4 55 26 ,,	—	1	20
4 56 00 ,,	—	3	39
5 09 40 ,,	—	1	19
5 18 00 ,,	1.2	2	29
5 19 04 ,,	2.1	2	21
JULY 5	sec.	μ	sec.
5 20 24 p.m.	—	1	16
5 22 33 ,,	—	4	22
5 25 49 ,,	—	2	23
5 29 52 ,,	—	1	15
5 30 14 ,,	—	1	12
5 30 58 ,,	—	1	18
5 44 25 ,,	1.3	1	25
5 47 21 ,,	2.9	3	—
5 47 31 ,,	—	2	23
5 50 34 ,,	—	1	15
5 52 47 ,,	—	1	14
5 54 59 ,,	—	1	16
5 55 56 ,,	—	1	13
5 56 38 ,,	—	1	18
6 01 07 ,,	—	1	14
6 02 53 ,,	—	1	—
6 03 03 ,,	1.8	1	19
6 04 49 ,,	—	1	26
6 11 18 ,,	—	1	19
6 12 47 ,,	2.0	2	23
6 15 13 ,,	—	1	12
6 16 55 ,,	—	1	10
6 18 10 ,,	1.5	1	13
6 19 40 ,,	—	2	23
6 27 03 ,,	2.4	1	21
6 27 28 ,,	—	1	24
6 30 09 ,,	—	1	16
6 43 53 ,,	—	2	19
6 48 45 ,,	—	1	27
6 49 45 ,,	—	1	19
6 54 46 ,,	—	1	16
6 59 13 ,,	—	1	24
6 59 51 ,,	—	1	21
7 06 58 ,,	2.7	2	23
7 08 22 ,,	1.8	3	40
7 10 10 ,,	—	3	36
7 11 40 ,,	—	1	32
7 13 44 ,,	—	1	20
7 14 24 ,,	—	1	17
7 21 24 ,,	—	3	36

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
JULY 5	sec.	μ	sec.	**JULY 5**	sec.	μ	sec.
7 22 06 p.m.	—	1	12	8 21 42 p.m.	2.7	1	27
7 22 21 ,,	—	2	24	8 22 15 ,,	—	1	13
7 23 37 ,,	—	1	16	8 22 31 ,,	—	1	13
7 24 06 ,,	—	1	15	8 22 56 ,,	—	1	11
7 25 15 ,,	—	1	25	8 23 39 ,,	—	1	24
7 27 00 ,,	—	1	38	8 26 05 ,,	—	1	12
7 27 51 ,,	—	1	24	8 26 35 ,,	—	1	19
7 28 23 ,,	—	1	30	8 29 04 ,,	—	1	28
7 33 46 ,,	—	3	19	8 29 54 ,,	—	1	35
7 39 41 ,,	—	1	16	8 30 57 ,,	—	1	17
7 40 42 ,,	—	1	16	8 32 30 ,,	—	1	28
7 41 06 ,,	—	1	17	8 33 18 ,,	—	1	49
7 41 33 ,,	—	1	22	8 35 09 ,,	—	2	21
7 42 11 ,,	—	1	11	8 35 35 ,,	—	1	20
7 42 38 ,,	—	1	16	8 36 21 ,,	—	1	29
7 44 44 ,,	—	1	13	8 36 56 ,,	—	1	20
7 45 25 ,,	—	2	22	8 37 17 ,,	2.6	1	33
7 45 52 ,,	—	1	16	8 38 24 ,,	—	1	19
7 46 16 ,,	—	1	21	8 38 47 ,,	—	1	19
7 46 37 ,,	—	1	21	8 39 18 ,,	—	1	19
7 48 02 ,,	—	1	19	8 40 26 ,,	—	1	13
7 52 06 ,,	—	1	27	8 40 46 ,,	—	1	—
7 57 35 ,,	—	1	21	8 41 13 ,,	—	1	10
7 58 51 ,,	—	1	20	8 41 35 ,,	—	1	17
8 02 44 ,,	—	1	15	8 42 00 ,,	—	1	15
8 06 41 ,,	—	1	15	8 42 19 ,,	—	1	19
8 07 51 ,,	—	1	12	8 42 44 ,,	—	1	22
8 08 04 ,,	1.3	3	47	8 43 37 ,,	—	1	26
8 10 35 ,,	—	1	14	8 44 51 ,,	—	1	16
8 12 21 ,,	—	1	14	8 45 18 ,,	—	1	—
8 13 27 ,,	—	1	23	8 45 30 ,,	—	1	23
8 14 33 ,,	—	1	21	8 46 12 ,,	—	1	16
8 15 12 ,,	—	2	37	8 47 26 ,,	—	1	20
8 16 11 ,,	—	2	28	8 48 20 ,,	—	1	26
8 17 49 ,,	—	2	29	8 48 58 ,,	—	1	22
8 18 50 ,,	—	1	26	8 49 25 ,,	—	1	25
8 19 23 ,,	—	1	25	8 49 51 ,,	2.6	1	20
8 19 52 ,,	—	1	19	8 50 17 ,,	—	1	22
8 20 29 ,,	—	1	18	8 51 33 ,,	—	1	12
8 20 52 ,,	—	2	25	8 51 49 ,,	—	2	22

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
JULY 5	sec.	μ	sec.	**JULY 5**	sec.	μ	sec.
8 52 30 p.m.	1.9	2	26	9 11 15 p.m.	—	1	—
8 53 25 ,,	2.0	3	—	9 11 40 ,,	—	1	19
8 53 49 ,,	—	1	20	9 12 16 ,,	—	1	19
8 54 21 ,,	—	2	20	9 13 07 ,,	—	1	15
8 54 44 ,,	—	1	16	9 13 44 ,,	—	1	21
8 55 11 ,,	—	1	14	9 14 31 ,,	2.8	1	32
8 55 53 ,,	—	1	13	9 15 09 ,,	—	1	17
8 56 21 ,,	—	1	28	9 15 43 ,,	2.9	1	25
8 57 10 ,,	—	1	17	9 16 09 ,,	—	1	22
8 58 02 ,,	—	1	17	9 16 36 ,,	—	1	—
8 58 21 ,,	—	1	30	9 16 52 ,,	—	1	—
8 59 24 ,,	—	1	—	9 17 11 ,,	—	1	29
8 59 36 ,,	—	1	25	9 17 57 ,,	—	1	—
9 00 30 ,,	—	1	—	9 18 15 ,,	—	1	—
9 00 45 ,,	—	2	—	9 18 34 ,,	—	1	21
9 01 20 ,,	—	1	—	9 19 14 ,,	—	1	—
9 01 31 ,,	—	1	—	9 19 29 ,,	—	2	—
9 01 44 ,,	—	3	27	9 19 46 ,,	—	1	21
9 02 15 ,,	3.2	2	39	9 20 10 ,,	—	2	—
9 03 18 ,,	—	2	—	9 20 27 ,,	—	1	—
9 03 36 ,,	—	1	26	9 20 50 ,,	—	2	—
9 04 08 ,,	—	3	29	9 20 59 ,,	—	1	—
9 04 48 ,,	—	1	25	9 21 24 ,,	—	2	20
9 05 17 ,,	—	1	—	9 21 47 ,,	2.6	1	19
9 05 33 ,,	—	1	—	9 22 08 ,,	—	1	20
9 05 53 ,,	—	1	—	9 22 34 ,,	—	1	—
9 06 13 ,,	—	4	—	9 22 43 ,,	—	2	—
9 06 33 ,,	—	1	—	9 22 57 ,,	—	1	—
9 06 49 ,,	—	2	—	9 23 14 ,,	—	1	20
9 07 08 ,,	—	1	—	9 23 52 ,,	—	2	13
9 07 25 ,,	—	1	—	9 24 06 ,,	—	1	24
9 07 43 ,,	—	1	30	9 24 33 ,,	—	1	—
9 08 16 ,,	—	1	—	9 24 52 ,,	—	1	—
9 08 26 ,,	—	3	—	9 25 08 ,,	—	1	26
9 08 44 ,,	—	2	—	9 25 40 ,,	2.2	2	—
9 08 54 ,,	—	1	23	9 26 07 ,,	—	2	—
9 09 20 ,,	—	1	15	9 26 34 ,,	—	2	—
9 09 42 ,,	1.7	6	—	9 26 49 ,,	5.5	1	12
9 10 02 ,,	—	1	38	9 27 08 ,,	—	5	—
9 10 59 ,,	—	1	—	9 27 28 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
JULY 5	sec.	μ	sec.	JULY 5	sec.	μ	sec.
9 27 44 p.m.	—	1	—	9 48 48 p.m.	—	1	—
9 27 59 ,,	—	1	—	9 48 58 ,,	—	1	—
9 28 26 ,,	—	1	25	9 49 11 ,,	—	1	—
9 28 53 ,,	6.0	4	—	9 49 17 ,,	—	1	—
9 29 18 ,,	—	1	25	9 49 35 ,,	—	1	21
9 30 04 ,,	3.1	1	—	9 49 59 ,,	—	1	20
9 30 20 ,,	2.4	2	—	9 50 26 ,,	—	1	17
9 30 36 ,,	—	1	—	9 50 46 ,,	—	1	—
9 30 47 ,,	—	1	—	9 50 54 ,,	—	1	—
9 31 05 ,,	—	1	24	9 51 21 ,,	—	1	25
9 31 52 ,,	—	1	14	9 52 08 ,,	—	1	—
9 33 17 ,,	—	1	29	9 52 23 ,,	—	1	—
9 34 19 ,,	3.6	1	19	9 52 45 ,,	—	1	26
9 34 46 ,,	3.6	1	23	9 53 29 ,,	—	1	—
9 35 09 ,,	3.0	1	30	9 53 37 ,,	—	1	—
9 36 11 ,,	—	1	—	9 53 48 ,,	—	2	—
9 36 23 ,,	3.0	1	29	9 54 05 ,,	—	1	—
9 37 09 ,,	—	1	22	9 54 15 ,,	—	1	15
9 37 48 ,,	—	1	15	9 54 36 ,,	3.0	1	24
9 38 17 ,,	3.6	1	—	9 55 44 ,,	3.0	1	18
9 38 32 ,,	3.6	1	—	9 56 04 ,,	—	1	—
9 38 48 ,,	3.0	1	32	9 56 20 ,,	—	2	24
9 39 27 ,,	—	1	36	9 56 48 ,,	4.8	2	—
9 40 33 ,,	3.0	1	18	9 57 06 ,,	—	2	30
9 41 03 ,,	—	1	15	9 57 43 ,,	—	1	16
9 41 27 ,,	—	1	13	9 58 14 ,,	—	1	15
9 41 51 ,,	3.6	1	32	9 58 40 ,,	2.9	2	—
9 42 26 ,,	—	1	—	9 58 57 ,,	—	1	—
9 42 37 ,,	—	2	21	9 59 07 ,,	3.9	2	—
9 43 24 ,,	—	1	15	9 59 17 ,,	—	1	27
9 43 56 ,,	—	1	25	9 59 56 ,,	3.9	2	17
9 44 28 ,,	—	1	—	10 00 20 ,,	—	1	—
9 44 39 ,,	—	1	16	10 00 37 ,,	—	1	—
9 44 57 ,,	—	1	31	10 00 57 ,,	—	1	18
9 46 08 ,,	2.9	2	29	10 01 25 ,,	4.4	1	23
9 46 41 ,,	—	1	—	10 01 54 ,,	—	1	18
9 46 52 ,,	—	3	—	10 02 18 ,,	—	1	—
9 47 20 ,,	—	1	—	10 02 32 ,,	—	1	23
9 47 46 ,,	—	1	21	10 03 01 ,,	—	1	—
9 48 19 ,,	2.1	2	—	10 03 16 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
JULY 5	sec.	μ	sec.	JULY 5	sec.	μ	sec.
10 03 27 p.m.	—	1	12	10 29 47 p.m.	—	3	41
10 04 07 ,,	—	1	21	10 30 42 ,,	—	1	26
10 05 10 ,,	—	1	12	10 31 13 ,,	—	1	16
10 06 57 ,,	—	1	17	10 31 32 ,,	—	1	16
10 08 06 ,,	—	1	18	10 33 13 ,,	—	1	33
10 08 27 ,,	—	3	—	10 33 53 ,,	—	1	18
10 09 03 ,,	—	1	18	10 34 33 ,,	—	1	—
10 09 42 ,,	—	1	18	10 34 44 ,,	—	1	23
10 10 04 ,,	—	1	17	10 35 29 ,,	—	1	—
10 10 59 ,,	—	1	23	10 35 40 ,,	—	1	25
10 12 40 ,,	3.7	1	26	10 36 15 ,,	—	1	16
10 13 12 ,,	—	1	—	10 36 55 ,,	—	1	—
10 13 32 ,,	—	1	18	10 37 08 ,,	—	1	23
10 14 07 ,,	4.4	3	—	10 37 37 ,,	4.4	2	—
10 14 23 ,,	—	1	13	10 37 58 ,,	—	1	—
10 14 38 ,,	—	1	11	10 38 13 ,,	—	1	16
10 14 51 ,,	—	1	23	10 38 32 ,,	3.5	1	21
10 16 09 ,,	—	1	20	10 39 18 ,,	—	1	24
10 17 03 ,,	—	1	—	10 41 35 ,,	4.6	1	20
10 17 13 ,,	2.4	1	21	10 42 37 ,,	2.6	1	32
10 17 34 ,,	—	1	14	10 43 21 ,,	—	1	19
10 17 54 ,,	—	1	—	10 43 47 ,,	4.6	2	31
10 18 13 ,,	—	1	19	10 46 01 ,,	4.5	1	33
10 21 16 ,,	—	1	14	10 47 00 ,,	—	1	—
10 21 42 ,,	—	1	—	10 47 12 ,,	4.7	2	28
10 21 55 ,,	3.8	1	14	10 47 45 ,,	—	1	15
10 22 12 ,,	—	1	—	10 48 20 ,,	—	3	42
10 22 27 ,,	—	1	20	10 49 15 ,,	4.8	4	57
10 23 28 ,,	—	1	29	10 51 28 ,,	—	1	12
10 24 06 ,,	—	1	20	10 52 05 ,,	5.0	2	—
10 24 30 ,,	4.6	2	—	10 52 23 ,,	—	1	—
10 24 48 ,,	—	1	16	10 52 39 ,,	—	1	—
10 25 14 ,,	—	1	24	10 52 51 ,,	—	1	—
10 25 42 ,,	—	1	16	10 53 06 ,,	—	1	31
10 26 19 ,,	—	1	26	10 54 10 ,,	—	1	21
10 27 14 ,,	—	1	—	10 54 45 ,,	—	1	20
10 27 29 ,,	—	1	—	10 55 14 ,,	—	1	26
10 27 39 ,,	—	1	—	10 57 53 ,,	—	1	23
10 28 06 ,,	—	1	—	10 58 26 ,,	—	1	32
10 28 18 ,,	3.3	1	44	10 59 20 ,,	—	1	22

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
JULY 5	sec.	μ	sec.	**JULY 5**	sec.	μ	sec.
10 59 59 p.m.	—	1	18	11 30 09 p.m.	—	1	12
11 01 46 ,,	2.4	1	33	11 30 51 ,,	—	1	22
11 02 21 ,,	—	1	24	11 31 21 ,,	—	1	28
11 03 11 ,,	—	1	26	11 32 20 ,,	—	1	14
11 03 54 ,,	—	1	36	11 32 51 ,,	—	1	—
11 05 17 ,,	4.3	1	30	11 33 16 ,,	—	2	—
11 06 01 ,,	—	1	27	11 33 34 ,,	—	1	22
11 06 35 ,,	—	1	13	11 34 00 ,,	—	1	—
11 07 19 ,,	3.9	2	42	11 34 15 ,,	3.5	2	—
11 08 14 ,,	—	1	32	11 34 39 ,,	—	1	25
11 08 52 ,,	3.0	3	55	11 35 55 ,,	—	1	14
11 10 01 ,,	—	1	19	11 36 28 ,,	—	1	10
11 10 29 ,,	—	1	—	11 37 02 ,,	—	1	16
11 10 56 ,,	—	1	19	11 37 52 ,,	—	3	52
11 11 19 ,,	—	1	—	11 39 08 ,,	—	1	15
11 11 39 ,,	—	1	18	11 39 27 ,,	—	1	11
11 13 44 ,,	2.5	1	20	11 39 50 ,,	—	1	—
11 14 11 ,,	—	1	35	11 40 20 ,,	—	1	—
11 15 08 ,,	—	1	15	11 40 41 ,,	—	1	—
11 15 34 ,,	5.0	1	38	11 41 08 ,,	—	1	22
11 16 32 ,,	2.6	1	—	11 42 11 ,,	2.8	2	25
11 16 52 ,,	—	1	26	11 42 41 ,,	—	1	31
11 17 38 ,,	3.0	1	20	11 43 22 ,,	—	1	—
11 18 02 ,,	—	1	33	11 43 49 ,,	—	1	—
11 18 49 ,,	3.8	1	28	11 44 02 ,,	—	5	—
11 19 44 ,,	—	1	20	11 44 16 ,,	—	5	—
11 20 20 ,,	2.4	1	18	11 44 34 ,,	—	1	—
11 21 47 ,,	—	1	23	11 44 49 ,,	—	1	30
11 23 54 ,,	—	1	33	11 45 22 ,,	—	1	—
11 24 34 ,,	—	1	18	11 45 43 ,,	—	1	23
11 25 10 ,,	—	2	32	11 46 08 ,,	—	1	26
11 25 45 ,,	—	1	—	11 46 47 ,,	—	1	19
11 25 59 ,,	—	1	15	11 47 17 ,,	—	1	36
11 26 30 ,,	2.3	2	23	11 47 58 ,,	—	1	22
11 27 01 ,,	—	1	19	11 48 49 ,,	—	1	28
11 28 12 ,,	—	1	23	11 49 49 ,,	—	1	50
11 28 38 ,,	—	2	—	11 51 27 ,,	—	1	20
11 28 53 ,,	—	2	32	11 53 53 ,,	—	6	35
11 29 43 ,,	—	1	15	11 54 32 ,,	—	1	31
11 29 59 ,,	—	1	—	11 55 04 ,,	—	1	25

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
JULY 5	sec.	μ	sec.
11 56 44 p.m.	—	1	—
11 56 52 ,,	—	1	31
11 57 37 ,,	—	1	27
11 58 08 ,,	—	1	20
11 58 41 ,,	1.9	1	31
JULY 6			
0 00 53 a.m.	—	1	38
0 01 53 ,,	—	1	37
0 02 38 ,,	—	2	35
0 03 17 ,,	—	1	23
0 04 18 ,,	—	1	25
0 04 53 ,,	—	2	—
0 05 17 ,,	—	1	23
0 08 16 ,,	—	1	28
0 09 29 ,,	2.4	1	29
0 12 06 ,,	—	1	33
0 13 35 ,,	—	1	31
0 14 38 ,,	—	1	22
0 15 12 ,,	2.2	1	26
0 16 34 ,,	—	1	27
0 17 14 ,,	1.3	1	25
0 19 04 ,,	—	1	24
0 19 44 ,,	—	1	26
0 20 17 ,,	—	1	23
0 21 59 ,,	2.8	2	25
0 24 46 ,,	1.7	2	31
0 27 43 ,,	—	1	20
0 28 51 ,,	2.4	1	20
0 30 09 ,,	—	1	23
0 33 06 ,,	2.4	1	35
0 34 10 ,,	—	1	24
0 35 11 ,,	—	1	29
0 36 00 ,,	3.3	1	27
0 36 42 ,,	—	1	14
0 37 05 ,,	—	1	—
0 37 18 ,,	2.7	1	19
0 37 41 ,,	—	1	17
0 40 16 ,,	—	1	16
0 42 00 ,,	1.7	1	17
0 43 33 ,,	3.3	2	31
0 44 26 ,,	—	1	15
JULY 6	sec.	μ	sec.
0 45 22 a.m.	2.1	2	25
0 46 58 ,,	—	1	13
0 54 03 ,,	3.0	1	17
0 57 15 ,,	2.4	1	15
0 57 46 ,,	—	1	34
1 00 52 ,,	1.9	1	25
1 01 45 ,,	—	1	18
1 04 21 ,,	1.6	1	19
1 06 18 ,,	—	1	12
1 07 39 ,,	2.3	1	18
1 08 17 ,,	—	1	11
1 11 40 ,,	—	1	15
1 12 35 ,,	—	1	15
1 14 57 ,,	0.9	2	27
1 17 03 ,,	2.6	2	31
1 18 49 ,,	1.9	1	26
1 22 33 ,,	2.2	1	—
1 22 39 ,,	—	1	—
1 22 52 ,,	—	1	—
1 22 59 ,,	—	1	18
1 24 15 ,,	1.9	1	24
1 25 20 ,,	1.8	1	30
1 27 32 ,,	—	2	30
1 28 10 ,,	—	1	18
1 28 47 ,,	—	1	—
1 28 56 ,,	3.8	1	26
1 30 15 ,,	—	1	—
1 30 28 ,,	2.3	1	23
1 31 03 ,,	—	1	18
1 31 26 ,,	—	1	23
1 32 06 ,,	—	1	16
1 32 37 ,,	—	1	16
1 33 04 ,,	6.9	2	39
1 33 55 ,,	—	1	24
1 34 38 ,,	—	1	—
1 34 54 ,,	—	1	—
1 35 08 ,,	2.8	1	24
1 36 07 ,,	—	1	24
1 37 30 ,,	—	1	17
1 37 50 ,,	—	1	31

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
JULY 6	sec.	μ	sec.	**JULY 6**	sec.	μ	sec.
1 39 36 a.m.	—	1	19	2 10 14 a.m.	—	1	—
1 40 25 „	2.5	1	19	2 10 35 „	—	1	—
1 40 48 „	3.1	1	35	2 10 49 „	—	1	—
1 42 15 „	—	1	13	2 11 11 „	1.8	2	43
1 42 29 „	—	1	21	2 12 55 „	3.5	1	57
1 43 15 „	1.9	1	22	2 14 21 „	2.2	1	24
1 44 20 „	3.7	2	29	2 15 29 „	—	1	13
1 46 29 „	2.7	1	29	2 15 47 „	3.8	1	34
1 47 34 „	2.8	1	19	2 16 30 „	—	1	—
1 48 08 „	—	1	20	2 16 40 „	2.3	1	27
1 48 58 „	—	1	25	2 17 32 „	8.3	2	—
1 49 44 „	—	1	—	2 18 03 „	—	1	—
1 50 03 „	—	1	26	2 18 16 „	—	1	—
1 51 19 „	—	1	19	2 18 40 „	—	1	26
1 52 03 „	—	1	22	2 19 45 „	—	1	—
1 52 28 „	—	1	20	2 20 00 „	3.2	1	24
1 52 54 „	—	1	24	2 20 36 „	5.2	1	26
1 54 41 „	—	1	24	2 21 17 „	—	1	24
1 55 47 „	—	1	13	2 22 18 „	—	1	29
1 56 03 „	—	1	—	2 24 02 „	0.8	1	35
1 56 27 „	—	1	—	2 24 42 „	—	1	26
1 56 46 „	—	1	21	2 25 40 „	2.9	1	—
1 57 17 „	—	1	20	2 25 51 „	—	1	—
1 57 44 „	—	1	21	2 26 13 „	—	1	—
1 58 55 „	—	1	—	2 26 44 „	—	3	—
1 59 15 „	—	1	20	2 27 00 „	—	2	—
1 59 52 „	—	1	33	2 27 21 „	—	2	—
2 00 47 „	2.3	1	24	2 27 38 „	—	4	—
2 01 21 „	—	1	14	2 27 53 „	—	4	—
2 02 43 „	—	1	21	2 28 26 „	—	1	—
2 03 22 „	2.4	1	—	2 28 43 „	3.2	1	29
2 03 45 „	—	1	33	2 29 19 „	—	2	—
2 05 32 „	—	1	26	2 29 35 „	—	1	23
2 06 20 „	2.1	2	—	2 30 28 „	—	1	25
2 06 47 „	—	1	28	2 31 35 „	—	2	39
2 07 41 „	—	1	—	2 32 18 „	—	1	13
2 07 53 „	—	1	31	2 33 18 „	—	1	14
2 08 32 „	2.1	1	37	2 33 54 „	—	1	29
2 09 44 „	—	1	—	2 34 28 „	—	1	—
2 09 54 „	—	2	—	2 34 42 „	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
JULY 6	sec.	μ	sec.	**JULY 6**	sec.	μ	sec.
2 35 00 a.m.	—	1	15	3 10 21 a.m.	1.3	1	14
2 35 59 ,,	—	1	19	3 11 04 ,,	—	1	15
2 36 24 ,,	—	1	—	3 12 38 ,,	1.5	1	23
2 36 51 ,,	—	2	—	3 14 11 ,,	—	1	21
2 37 17 ,,	—	1	—	3 15 36 ,,	—	1	10
2 37 34 ,,	—	1	19	3 16 16 ,,	—	1	15
2 38 02 ,,	1.6	2	—	3 17 38 ,,	—	1	15
2 38 27 ,,	—	1	18	3 18 26 ,,	1.8	1	23
2 38 58 ,,	—	1	—	3 25 24 ,,	—	1	29
2 39 25 ,,	5.8	2	36	3 27 53 ,,	—	1	—
2 40 25 ,,	—	1	29	3 28 01 ,,	—	1	—
2 40 58 ,,	—	1	—	3 28 19 ,,	—	1	19
2 41 23 ,,	—	1	—	3 30 35 ,,	2.0	2	29
2 41 42 ,,	—	1	—	3 32 03 ,,	—	1	24
2 41 54 ,,	3.2	2	43	3 32 35 ,,	—	1	17
2 42 44 ,,	—	1	19	3 33 16 ,,	—	1	14
2 43 26 ,,	—	1	16	3 34 02 ,,	—	1	26
2 44 12 ,,	—	1	14	3 34 40 ,,	—	1	13
2 45 10 ,,	—	2	—	3 35 00 ,,	—	1	21
2 45 33 ,,	—	1	30	3 36 39 ,,	—	1	16
2 46 16 ,,	—	1	—	3 42 04 ,,	—	1	13
2 46 28 ,,	—	1	—	3 42 19 ,,	—	1	13
2 47 05 ,,	3.1	2	—	3 43 17 ,,	—	1	19
2 48 06 ,,	—	1	—	3 44 01 ,,	—	1	14
2 48 38 ,,	—	1	13	3 44 24 ,,	—	1	25
2 49 35 ,,	—	1	26	3 45 32 ,,	—	1	—
2 50 59 ,,	—	1	—	3 45 44 ,,	—	2	—
2 51 12 ,,	1.3	1	16	3 46 06 ,,	—	1	22
2 53 33 ,,	—	1	13	3 46 32 ,,	—	1	23
2 54 09 ,,	—	1	13	3 47 54 ,,	—	1	31
2 59 03 ,,	—	1	—	3 49 19 ,,	—	1	11
2 59 14 ,,	—	1	22	3 50 13 ,,	—	2	33
3 00 54 ,,	—	1	18	3 51 34 ,,	—	1	17
3 01 36 ,,	—	1	13	3 52 04 ,,	—	1	—
3 03 00 ,,	—	1	15	3 52 18 ,,	—	2	—
3 04 43 ,,	—	2	28	3 52 44 ,,	—	1	49
3 05 19 ,,	—	1	15	3 53 39 ,,	—	1	27
3 06 30 ,,	1.5	1	25	3 55 11 ,,	—	1	13
3 07 11 ,,	—	1	21	3 55 44 ,,	—	1	20
3 09 37 ,,	—	1	14	3 56 16 ,,	—	1	23

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
JULY 6	sec.	μ	sec.	JULY 6	sec.	μ	sec.
3 56 45 a.m.	—	1	23	4 27 38 a.m.	—	1	—
3 57 14 „	—	1	33	4 28 12 „	—	1	25
3 59 03 „	2.6	2	43	4 29 18 „	—	1	35
4 00 17 „	—	1	22	4 30 17 „	—	1	21
4 00 44 „	—	1	—	4 30 59 „	—	1	—
4 01 00 „	2.3	2	36	4 31 17 „	—	2	23
4 01 45 „	1.7	1	15	4 31 51 „	—	1	—
4 02 16 „	1.7	1	—	4 32 17 „	—	1	—
4 02 35 „	—	1	20	4 32 37 „	—	1	27
4 03 10 „	2.2	2	22	4 33 09 „	—	1	—
4 04 17 „	—	1	—	4 33 25 „	—	2	31
4 04 37 „	—	1	—	4 34 07 „	3.9	2	30
4 05 00 „	—	1	—	4 34 59 „	—	1	—
4 05 15 „	—	1	—	4 35 13 „	2.6	1	31
4 05 31 „	—	1	37	4 36 08 „	—	1	14
4 06 59 „	—	2	29	4 36 32 „	—	1	14
4 08 59 „	—	1	25	4 37 36 „	—	1	24
4 09 28 „	—	1	21	4 38 11 „	—	1	—
4 10 57 „	4.5	1	36	4 38 22 „	4.3	1	31
4 13 35 „	—	1	30	4 39 17 „	—	1	—
4 14 12 „	3.8	1	23	4 39 33 „	—	1	—
4 14 49 „	—	1	33	4 39 53 „	—	1	17
4 15 28 „	—	1	25	4 40 45 „	—	1	—
4 16 37 „	—	1	26	4 41 02 „	—	1	37
4 17 11 „	—	1	—	4 41 52 „	—	1	31
4 17 40 „	—	1	33	4 43 12 „	—	1	22
4 18 27 „	2.6	1	29	4 43 45 „	—	1	29
4 19 00 „	—	1	41	4 44 53 „	—	1	16
4 20 01 „	—	1	17	4 45 32 „	2.7	1	19
4 20 42 „	—	1	39	4 46 27 „	—	1	33
4 22 07 „	4.9	2	—	4 48 42 „	—	1	21
4 22 30 „	—	1	—	4 49 25 „	3.2	1	26
4 22 51 „	—	1	21	4 50 11 „	3.4	1	23
4 23 18 „	—	1	28	4 51 31 „	—	1	30
4 23 55 „	—	2	—	4 52 32 „	—	1	—
4 24 17 „	—	1	—	4 52 48 „	—	1	18
4 24 32 „	—	1	30	4 55 01 „	2.7	1	27
4 25 34 „	2.9	1	—	4 55 47 „	3.4	1	19
4 26 08 „	—	1	—	4 57 02 „	1.9	1	29
4 26 42 „	—	1	34	4 58 01 „	2.0	2	34

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
JULY 6	sec.	μ	sec.	JULY 6	sec.	μ	sec.
4 58 44 a.m.	—	1	18	5 43 23 a.m.	—	2	—
4 59 29 ,,	3.9	1	19	5 43 45 ,,	—	1	32
4 59 58 ,,	—	1	13	5 45 05 ,,	—	1	28
5 00 25 ,,	—	1	18	5 45 40 ,,	—	2	34
5 00 47 ,,	—	1	28	5 47 09 ,,	—	1	—
5 01 21 ,,	—	1	48	5 47 25 ,,	—	1	14
5 02 38 ,,	—	1	20	5 47 51 ,,	—	1	—
5 04 07 ,,	—	1	—	5 48 11 ,,	—	1	23
5 04 25 ,,	—	1	—	5 48 42 ,,	—	1	12
5 04 50 ,,	—	2	—	5 48 56 ,,	—	1	—
5 05 28 ,,	—	1	27	5 49 24 ,,	—	1	12
5 06 04 ,,	—	1	16	5 49 55 ,,	—	1	24
5 09 46 ,,	—	1	—	5 50 23 ,,	—	1	—
5 10 14 ,,	—	1	14	5 50 33 ,,	—	1	—
5 10 58 ,,	2.8	2	23	5 50 53 ,,	—	1	—
5 12 31 ,,	2.7	1	28	5 51 00 ,,	—	1	—
5 13 56 ,,	—	1	19	5 51 11 ,,	—	1	27
5 16 52 ,,	3.8	1	39	5 51 55 ,,	5.3	2	39
5 17 45 ,,	—	1	33	5 52 51 ,,	—	1	12
5 18 34 ,,	2.8	2	52	5 53 24 ,,	—	1	14
5 20 17 ,,	2.7	2	31	5 53 49 ,,	—	1	—
5 21 17 ,,	—	1	13	5 54 08 ,,	—	3	—
5 21 44 ,,	—	1	22	5 54 25 ,,	—	1	18
5 25 15 ,,	—	1	—	5 54 54 ,,	—	1	23
5 26 08 ,,	—	1	26	5 55 32 ,,	—	1	23
5 28 54 ,,	—	1	31	5 56 32 ,,	—	1	27
5 29 59 ,,	2.9	1	—	5 58 02 ,,	—	1	—
5 30 13 ,,	—	1	—	5 58 15 ,,	—	1	23
5 34 43 ,,	—	1	23	5 59 17 ,,	7.4	3	45
5 35 27 ,,	—	1	16	6 00 09 ,,	—	1	33
5 36 14 ,,	3.4	2	24	6 02 20 ,,	2.5	2	25
5 36 56 ,,	—	1	15	6 03 41 ,,	—	2	—
5 38 59 ,,	—	1	24	6 04 09 ,,	2.1	2	—
5 39 30 ,,	—	1	13	6 04 20 ,,	—	4	42
5 39 52 ,,	—	1	18	6 05 16 ,,	2.7	2	—
5 40 40 ,,	—	1	16	6 05 43 ,,	—	2	40
5 41 10 ,,	—	2	—	6 07 38 ,,	—	2	28
5 41 44 ,,	—	1	—	6 08 14 ,,	—	1	26
5 42 12 ,,	1.6	2	39	6 09 17 ,,	—	1	22
5 43 06 ,,	—	1	—	6 09 45 ,,	—	1	22

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
JULY 6	sec.	μ	sec.	JULY 6	sec.	μ	sec.
6 10 12 a.m.	—	1	—	6 50 49 a.m.	—	1	—
6 10 28 ,,	—	1	—	6 51 41 ,,	—	1	31
6 10 48 ,,	—	1	38	6 52 42 ,,	—	1	13
6 12 12 ,,	2.2	2	—	6 53 24 ,,	—	1	12
6 12 33 ,,	—	2	34	6 53 46 ,,	—	1	20
6 13 18 ,,	—	1	14	6 54 41 ,,	—	2	—
6 13 47 ,,	—	4	35	6 54 58 ,,	—	1	17
6 20 17 ,,	—	1	—	6 55 51 ,,	—	1	11
6 20 44 ,,	—	1	20	6 57 30 ,,	—	1	12
6 21 29 ,,	—	1	14	6 57 49 ,,	1.1	2	24
6 22 15 ,,	—	1	27	7 00 06 ,,	—	2	18
6 23 01 ,,	—	1	—	7 01 44 ,,	—	2	22
6 23 23 ,,	—	2	35	7 02 15 ,,	—	2	14
6 24 54 ,,	—	1	13	7 02 47 ,,	—	1	16
6 26 05 ,,	—	1	33	7 04 02 ,,	—	1	21
6 27 39 ,,	—	1	17	7 04 51 ,,	—	1	17
6 28 19 ,,	—	2	—	7 05 30 ,,	—	1	14
6 28 46 ,,	—	1	—	7 06 38 ,,	—	1	24
6 29 07 ,,	—	1	30	7 07 18 ,,	—	1	21
6 29 58 ,,	2.0	4	—	7 08 16 ,,	—	1	—
6 30 18 ,,	—	1	—	7 08 28 ,,	—	1	—
6 30 38 ,,	—	1	—	7 08 40 ,,	—	1	17
6 31 01 ,,	—	1	—	7 10 12 ,,	—	1	13
6 31 24 ,,	—	1	35	7 12 10 ,,	—	1	11
6 32 19 ,,	3.7	2	34	7 12 56 ,,	—	1	15
6 33 06 ,,	2.6	2	—	7 14 12 ,,	—	1	12
6 33 33 ,,	—	1	20	7 14 46 ,,	—	1	17
6 37 39 ,,	2.9	1	30	7 16 12 ,,	—	1	21
6 38 26 ,,	—	1	36	7 17 46 ,,	—	1	16
6 39 18 ,,	—	1	24	7 20 06 ,,	—	1	14
6 39 55 ,,	1.7	1	33	7 21 44 ,,	—	1	11
6 40 31 ,,	3.2	2	—	7 24 34 ,,	—	1	13
6 40 49 ,,	—	2	—	7 27 37 ,,	—	1	19
6 41 09 ,,	—	1	17	7 30 02 ,,	—	1	11
6 44 09 ,,	1.8	4	50	7 34 08 ,,	—	1	16
6 45 16 ,,	—	1	—	7 34 40 ,,	—	1	18
6 45 39 ,,	—	1	21	7 35 03 ,,	—	1	14
6 46 12 ,,	—	1	22	7 35 26 ,,	—	1	14
6 49 25 ,,	—	1	23	7 36 49 ,,	—	1	16
6 50 28 ,,	—	3	—	7 37 47 ,,	—	1	13

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
JULY 6	sec.	μ	sec.	**JULY 6**	sec.	μ	sec.
7 41 06 a.m.	—	1	13	8 21 57 a.m.	—	2	—
7 46 48 „	—	1	—	8 22 06 „	—	2	—
7 47 06 „	—	1	—	8 22 23 „	—	1	13
7 47 29 „	—	1	—	8 23 08 „	2.1	2	19
7 48 46 „	—	1	22	8 23 35 „	—	1	16
7 49 22 „	4.3	1	23	8 25 24 „	—	1	16
7 50 45 „	—	1	20	8 26 24 „	1.3	1	22
7 51 16 „	3.7	1	21	8 26 50 „	—	1	11
7 53 10 „	—	1	18	8 27 14 „	—	1	8
7 53 54 „	—	1	13	8 27 36 „	2.6	1	—
7 54 33 „	—	1	15	8 27 48 „	—	1	—
7 56 18 „	0.7	1	8	8 28 10 „	0.6	1	—
7 56 37 „	—	1	11	8 28 25 „	—	1	12
7 57 04 „	—	1	11	8 30 37 „	—	1	19
7 57 57 „	—	1	20	8 31 10 „	—	1	10
7 58 19 „	2.2	1	—	8 32 17 „	—	1	16
7 58 53 „	—	1	9	8 32 57 „	—	1	25
7 59 15 „	3.4	2	20	8 33 44 „	3.7	2	—
8 01 15 „	—	1	—	8 34 11 „	3.4	1	16
8 01 30 „	4.4	4	21	8 34 52 „	—	1	17
8 03 03 „	—	1	14	8 35 29 „	—	1	—
8 03 23 „	—	1	16	8 36 45 „	—	1	12
8 04 03 „	—	1	22	8 38 04 „	3.3	1	—
8 04 47 „	3.7	3	—	8 38 23 „	—	1	12
8 05 17 „	—	1	—	8 39 38 „	—	1	13
8 05 29 „	3.3	2	—	8 40 32 „	—	1	24
8 05 44 „	—	1	—	8 41 15 „	—	1	—
8 06 07 „	—	1	22	8 41 39 „	—	1	19
8 07 13 „	—	1	12	8 43 33 „	—	1	14
8 09 54 „	—	1	18	8 45 19 „	—	1	19
8 10 26 „	2.9	3	—	8 47 29 „	—	1	19
8 10 41 „	—	1	15	8 47 52 „	—	1	—
8 12 46 „	3.3	3	32	8 48 06 „	—	2	—
8 13 44 „	2.8	2	22	8 48 24 „	—	1	—
8 14 35 „	—	1	25	8 48 36 „	—	1	12
8 16 55 „	—	1	8	8 49 19 „	—	1	13
8 19 53 „	2.9	2	18	8 49 51 „	—	1	14
8 20 14 „	—	2	—	8 50 16 „	—	1	13
8 20 33 „	—	1	23	8 51 06 „	2.6	1	23
8 21 27 „	2.4	1	20	8 51 44 „	—	1	13

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
JULY 6	sec.	μ	sec.	JULY 6	sec.	μ	sec.
8 52 03 a.m.	—	1	12	9 40 36 a.m.	—	1	—
8 52 44 ,,	—	1	11	9 41 18 ,,	—	1	20
8 53 38 ,,	—	1	—	9 42 30 ,,	—	1	—
8 54 16 ,,	—	1	17	9 42 48 ,,	—	3	—
8 55 18 ,,	—	1	17	9 43 15 ,,	—	3	—
8 56 35 ,,	—	1	—	9 43 45 ,,	—	3	—
8 56 41 ,,	—	2	—	9 44 11 ,,	—	2	—
8 56 59 ,,	—	2	14	9 44 36 ,,	—	1	—
8 58 12 ,,	—	1	12	9 44 56 ,,	—	2	—
8 58 45 ,,	—	1	15	9 45 12 ,,	—	1	13
8 59 17 ,,	—	1	13	9 45 40 ,,	—	1	—
9 00 26 ,,	—	1	—	9 46 01 ,,	—	1	—
9 00 44 ,,	4.3	2	22	9 46 27 ,,	—	2	26
9 17 29 ,,	—	2	—	9 47 31 ,,	—	1	—
9 17 50 ,,	—	1	15	9 47 58 ,,	—	3	54
9 19 00 ,,	—	1	—	9 49 00 ,,	—	2	—
9 19 12 ,,	—	2	—	9 49 51 ,,	—	5	—
9 19 21 ,,	—	1	14	9 51 04 ,,	—	1	—
9 21 18 ,,	2.6	3	45	9 51 19 ,,	—	1	—
9 22 15 ,,	—	1	13	9 52 20 ,,	—	2	—
9 22 34 ,,	—	2	23	9 52 44 ,,	—	1	—
9 23 55 ,,	—	1	12	9 52 51 ,,	—	1	19
9 24 46 ,,	—	1	13	9 53 28 ,,	—	1	—
9 26 46 ,,	—	1	15	9 53 50 ,,	—	2	—
9 27 19 ,,	—	1	11	9 54 11 ,,	—	1	—
9 27 41 ,,	—	1	17	9 54 31 ,,	—	1	—
9 28 03 ,,	—	1	19	9 54 52 ,,	—	1	20
9 29 13 ,,	—	1	—	10 06 29 ,,	—	2	22
9 29 36 ,,	—	1	13	10 07 19 ,,	—	1	18
9 30 21 ,,	—	1	—	10 08 41 ,,	—	4	—
9 30 43 ,,	—	1	18	10 08 58 ,,	—	1	—
9 31 38 ,,	—	1	28	10 09 20 ,,	—	1	—
9 34 09 ,,	—	1	14	10 09 53 ,,	—	2	—
9 34 51 ,,	—	1	14	10 10 12 ,,	—	1	15
9 36 59 ,,	—	1	16	10 11 00 ,,	—	1	17
9 38 01 ,,	—	1	14	10 13 01 ,,	—	1	—
9 38 29 ,,	—	1	13	10 13 25 ,,	—	1	15
9 38 52 ,,	—	1	—	10 14 46 ,,	—	1	—
9 39 23 ,,	—	1	—	10 15 03 ,,	—	1	13
9 39 39 ,,	—	1	15	10 15 46 ,,	—	1	13

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
JULY 6	sec.	μ	sec.	**JULY 6**	sec.	μ	sec.
10 16 25 a.m.	—	1	17	11 06 10 a.m.	—	1	—
10 16 50 ,,	—	1	—	11 06 25 ,,	—	1	—
10 17 11 ,,	—	1	—	11 06 29 ,,	—	1	—
10 17 45 ,,	—	1	—	11 06 47 ,,	—	1	16
10 18 09 ,,	—	1	—	11 08 21 ,,	—	1	13
10 18 26 ,,	—	1	25	11 09 26 ,,	—	1	17
10 19 19 ,,	—	2	—	11 10 20 ,,	—	1	—
10 19 57 ,,	—	2	34	11 10 29 ,,	—	2	—
10 20 43 ,,	—	1	37	11 10 44 ,,	—	2	—
10 21 39 ,,	—	1	27	11 11 18 ,,	—	1	—
10 24 16 ,,	—	1	16	11 11 40 ,,	—	2	—
10 25 15 ,,	—	2	—	11 12 14 ,,	—	1	—
10 26 02 ,,	—	1	20	11 12 35 ,,	—	2	—
10 27 53 ,,	—	1	14	11 13 02 ,,	—	1	—
10 28 47 ,,	—	1	13	11 13 22 ,,	—	1	—
10 31 41 ,,	—	1	13	11 13 42 ,,	—	1	—
10 32 00 ,,	—	1	34	11 14 50 ,,	—	1	17
10 33 43 ,,	—	1	—	11 16 11 ,,	—	1	15
10 34 12 ,,	—	1	—	11 16 45 ,,	—	1	16
10 34 36 ,,	—	2	—	11 17 43 ,,	—	1	—
10 35 18 ,,	—	1	11	11 18 20 ,,	1.9	1	22
10 37 23 ,,	—	1	12	11 19 14 ,,	—	1	—
10 40 19 ,,	—	1	19	11 19 32 ,,	—	2	28
10 40 58 ,,	—	1	21	11 20 58 ,,	—	1	14
10 45 56 ,,	—	1	—	11 23 49 ,,	—	1	—
10 46 09 ,,	—	1	16	11 24 15 ,,	—	1	—
10 47 48 ,,	—	1	18	11 24 36 ,,	—	1	18
10 51 18 ,,	—	1	13	11 24 59 ,,	—	1	15
10 54 42 ,,	—	2	—	11 25 29 ,,	—	1	—
10 55 02 ,,	—	1	17	11 25 39 ,,	—	2	—
10 55 21 ,,	—	1	15	11 25 46 ,,	—	2	—
10 55 58 ,,	—	1	—	11 26 01 ,,	—	1	—
10 56 31 ,,	—	1	12	11 26 15 ,,	—	1	14
10 57 12 ,,	—	1	18	11 26 42 ,,	—	1	—
10 58 03 ,,	—	1	14	11 27 32 ,,	—	1	—
10 58 48 ,,	—	1	15	11 28 03 ,,	—	2	22
10 59 15 ,,	—	1	17	11 29 11 ,,	—	2	—
11 02 53 ,,	—	1	14	11 29 43 ,,	6.6	4	71
11 03 48 ,,	—	1	15	11 31 08 ,,	—	1	—
11 05 11 ,,	—	1	13	11 31 32 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
JULY 6	sec.	μ	sec.	JULY 6	sec.	μ	sec.
11 31 47 a.m.	1.2	4	—	0 03 11 p.m.	—	1	28
11 32 39 ,,	—	2	—	0 03 51 ,,	—	1	31
11 34 07 ,,	—	1	—	0 04 46 ,,	—	2	—
11 34 48 ,,	—	1	—	0 05 17 ,,	—	1	32
11 35 10 ,,	—	1	—	0 06 59 ,,	—	1	31
11 35 39 ,,	—	1	—	0 08 17 ,,	—	1	28
11 36 07 ,,	—	2	—	0 08 52 ,,	—	2	—
11 36 47 ,,	—	4	—	0 09 05 ,,	—	1	19
11 37 07 ,,	—	1	22	0 10 09 ,,	—	1	17
11 37 44 ,,	—	1	—	0 11 00 ,,	—	1	—
11 38 11 ,,	—	1	15	0 11 19 ,,	—	1	17
11 39 46 ,,	—	2	27	0 13 43 ,,	—	1	18
11 40 35 ,,	—	2	—	0 14 18 ,,	—	1	12
11 41 27 ,,	—	1	28	0 14 44 ,,	—	1	19
11 42 06 ,,	—	1	17	0 15 40 ,,	—	1	31
11 43 15 ,,	—	1	24	0 16 25 ,,	—	1	19
11 43 49 ,,	—	2	27	0 17 16 ,,	—	1	—
11 44 47 ,,	—	1	21	0 17 45 ,,	—	1	—
11 45 54 ,,	—	1	19	0 18 06 ,,	—	1	31
11 46 26 ,,	—	1	18	0 20 44 ,,	—	1	23
11 47 50 ,,	—	2	—	0 22 04 ,,	—	1	—
11 48 20 ,,	—	1	—	0 22 33 ,,	—	1	31
11 48 38 ,,	—	2	—	0 24 00 ,,	—	1	17
11 48 55 ,,	—	1	—	0 24 44 ,,	—	1	18
11 49 10 ,,	—	1	—	0 26 43 ,,	—	1	14
11 52 33 ,,	—	1	—	0 27 59 ,,	—	1	14
11 52 48 ,,	—	1	—	0 29 40 ,,	—	1	16
11 53 04 ,,	—	1	—	0 30 21 ,,	—	1	—
11 53 25 ,,	—	2	37	0 30 39 ,,	—	1	24
11 54 29 ,,	—	1	29	0 31 48 ,,	—	1	12
11 57 09 ,,	—	1	27	0 35 54 ,,	—	1	13
11 57 38 ,,	—	1	—	0 36 09 ,,	—	1	13
11 57 51 ,,	—	1	28	0 41 32 ,,	—	1	12
11 58 20 ,,	—	2	—	0 42 23 ,,	—	2	26
11 58 48 ,,	—	1	24	0 46 22 ,,	—	1	15
11 59 41 ,,	—	1	—	0 48 13 ,,	—	1	11
0 00 00 p.m.	—	1	22	0 57 38 ,,	—	1	13
0 01 49 ,,	—	2	—	1 06 45 ,,	—	1	—
0 02 10 ,,	—	1	17	1 07 12 ,,	—	1	17
0 02 51 ,,	—	1	—	1 08 18 ,,	—	1	14

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
JULY 6	sec.	μ	sec.	**JULY 7**	sec.	μ	sec.
1 12 45 p.m.	—	1	16	4 45 41 a.m.	—	1	24
1 21 39 ,,	—	1	17	4 46 16 ,,	2.9	2	37
1 26 07 ,,	—	1	13	5 23 45 ,,	—	1	—
1 27 25 ,,	—	1	12	5 23 56 ,,	—	1	—
1 38 57 ,,	—	1	11	5 24 09 ,,	—	1	13
1 43 43 ,,	—	1	13	5 25 04 ,,	—	1	—
1 52 40 ,,	—	1	12	5 25 20 ,,	2.8	1	20
1 53 27 ,,	—	4	44	5 26 10 ,,	—	1	15
2 09 44 ,,	—	1	12	5 26 28 ,,	3.3	1	17
2 14 50 ,,	—	1	—	5 26 48 ,,	3.0	1	30
2 15 15 ,,	—	1	12	5 27 47 ,,	—	1	—
2 28 51 ,,	—	1	13	5 28 24 ,,	—	1	32
2 36 20 ,,	—	1	13	5 31 20 ,,	—	1	—
3 32 21 ,,	—	1	12	5 31 35 ,,	—	1	31
3 32 50 ,,	—	1	12	5 32 28 ,,	—	1	—
3 36 08 ,,	—	1	15	5 32 37 ,,	—	1	37
3 39 33 ,,	—	1	12	5 37 08 ,,	2.8	1	—
4 36 01 ,,	—	1	—	5 37 24 ,,	—	2	31
4 36 35 ,,	—	1	14	5 39 32 ,,	2.0	1	22
4 48 15 ,,	—	1	13	5 47 06 ,,	—	1	—
4 49 18 ,,	—	1	13	5 47 21 ,,	2.9	1	—
4 54 57 ,,	—	1	—	5 47 34 ,,	—	1	—
4 55 15 ,,	—	1	13	5 47 55 ,,	—	1	—
4 57 55 ,,	—	1	10	5 48 15 ,,	3.1	1	35
4 58 39 ,,	—	1	12	5 57 45 ,,	2.5	1	28
5 41 07 ,,	—	1	13	5 59 32 ,,	—	1	13
5 57 16 ,,	—	1	11	5 59 54 ,,	—	1	16
5 59 24 ,,	—	1	14	6 00 50 ,,	3.2	1	17
6 01 47 ,,	—	1	13	6 01 19 ,,	—	1	27
10 36 29 ,,	—	1	29	6 10 04 ,,	3.5	1	20
JULY 7							
0 03 05 a.m.	—	1	—	7 08 33 ,,	—	1	12
0 03 23 ,,	3.1	2	61	7 10 31 ,, (1)	—	17	120
0 09 03 ,,	4.5	1	13	6 15 21 p.m.(2)	4.8	3	48
0 11 14 ,,	—	1	23	8 19 53 ,,	2.3	1	—
4 39 02 ,,	5.0	1	30	8 20 01 ,,	2.3	1	37

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(1) Strong explosion.

(2) The transverse max.2a. $=2\mu$.

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
JULY 7	sec.	μ	sec.	**JULY 12**	sec.	μ	sec.
9 46 56 p.m.(1)	—	83	240	1 44 57 p.m.	2.5	1	17
JULY 8				1 48 15 ,,	3.4	1	25
5 25 24 a.m.(2)	—	103	240	4 48 27 ,,	—	1	20
5 29 41 ,,	—	1	14	5 08 00 ,,	2.9	1	20
5 30 40 ,,	—	1	—	5 51 19 ,,	—	1	19
5 31 15 ,,	—	1	—	5 51 45 ,,	—	1	33
6 08 10 ,,	—	1	25	**JULY 13**			
6 12 07 ,,	3.7	1	16	7 26 13 a.m.	—	2	48
6 22 22 ,,	—	1	—	4 01 19 p.m.(3)	0.67	123	138
6 26 38 ,,	4.4	1	—	4 05 37 ,,	4.7	1	27
8 21 56 ,,	—	2	—	4 08 20 ,,	3.2	1	24
8 22 21 ,,	—	1	35	**JULY 18**			
8 23 32 ,,	—	1	—	2 08 34 a.m.(4)	0.29	116	148
8 24 37 ,,	—	1	47	2 11 37 ,,	—	1	—
8 26 04 ,,	—	1	—	2 12 10 ,,	5.3	3	—
8 26 37 ,,	—	1	47	2 12 37 ,,	—	2	30
8 31 47 ,,	—	1	—	9 55 03 ,,	0.6	3	13
8 32 27 ,,	—	1	—	**JULY 19**			
8 34 04 ,,	—	1	—	4 14 32 a.m.	2.4	3	43
8 34 29 ,,	—	1	41	0 54 03 p.m.(5)	0.48	127	140
				JULY 26			
8 55 15 ,,	3.0	1	24	8 22 04 a.m.	—	1	27
5 47 06 p.m.	1.8	2	30	9 11 24 ,,	—	2	40
6 29 26 ,,	—	1	—	9 13 35 ,,	—	2	19
6 30 05 ,,	—	1	50				
JULY 10				9 13 56 ,,	—	2	13
9 20 29 a.m.	—	1	16	9 14 22 ,,	—	2	20
5 03 17 p.m.	—	1	23	9 14 47 ,,	—	2	15
5 45 16 ,,	—	1	15	4 37 45 p.m.	—	2	44
7 17 27 ,,	2.3	1	16	**JULY 27**			
7 17 55 ,,	2.0	2	16	0 53 52 p.m.	—	1	25
7 42 13 ,,	3.0	1	40	1 07 45 ,,	—	1	50
JULY 11							
9 53 09 a.m.	—	1	27	1 21 35 ,,	—	1	—
JULY 12				1 24 01 ,,	—	1	—
1 34 17 p.m.	2.5	1	20	1 32 27 ,,	—	1	60
1 34 49 ,,	2.5	1	20	1 38 54 ,,	—	1	—
1 44 48 ,,	2.6	1	—	1 38 40 ,,	—	1	—

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(1) Strong explosion: the transverse max. 2a. $=52\mu$.
(2) ,, : ,, max. 2a. $=80\mu$.
(3) ,, : ,, max. 2a. $=72\mu$.
(4) ,, : ,, max. 2a. $=90\mu$.
(5) Strong explosion.

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
JULY 27	sec.	μ	sec.
1 39 15 p.m.	—	1	—
1 40 01 ,,	—	1	—
1 46 29 ,,	—	1	25
1 47 38 ,,	—	1	—
1 48 38 ,,	—	1	50
3 22 12 ,,	—	1	—
4 09 40 ,,	—	1	—
10 54 45 ,,	2.9	2	37
11 02 48 ,,	—	1	—
AUG. 3			
7 41 44 p.m.(1)	2.6	1	17
7 42 54 ,,	—	1	23
7 43 23 ,,	—	1	—
7 44 03 ,,	—	1	—
7 44 33 ,,	—	1	—
7 56 46 ,,	—	2	25
7 57 58 ,,	—	1	—
7 58 48 ,,	—	1	—
7 59 09 ,,	—	1	—
7 59 44 ,,	—	1	13
8 02 51 ,,	—	1	40
8 03 48 ,,	—	1	16
8 06 45 ,,	—	1	—
8 07 10 ,,	—	1	—
8 07 37 ,,	—	1	—
8 08 09 ,,	—	1	—
8 08 30 ,,	—	1	—
8 09 12 ,,	—	1	—
8 09 43 ,,	—	1	—
8 10 15 ,,	—	1	31
8 11 13 ,,	—	1	—
8 11 35 ,,	—	1	—
8 11 52 ,,	—	1	—
8 12 17 ,,	—	1	—
8 12 49 ,,	—	1	—
8 13 48 ,,	—	1	—
AUG. 3	sec.	μ	sec.
8 14 10 p.m.	—	1	—
8 14 42 ,,	—	1	—
8 15 14 ,,	—	1	—
8 15 44 ,,	—	1	—
8 16 22 ,,	—	1	41
8 17 09 ,,	—	1	—
8 18 04 ,,	—	1	41
8 18 54 ,,	—	1	—
8 20 01 ,,	—	1	—
8 21 12 ,,	—	1	21
8 21 51 ,,	—	1	—
8 22 38 ,,	—	1	27
8 23 30 ,,	—	1	23
8 24 24 ,,	—	1	28
8 24 57 ,,	—	1	—
8 25 23 ,,	—	1	13
8 25 56 ,,	—	2	31
8 26 48 ,,	—	1	—
8 27 15 ,,	—	1	19
8 27 49 ,,	—	1	22
8 28 17 ,,	—	1	26
8 30 13 ,,	—	1	26
8 30 45 ,,	—	1	16
8 33 20 ,,	—	1	—
8 33 59 ,,	—	1	—
8 34 38 ,,	—	1	—
8 35 46 ,,	—	1	—
8 36 08 ,,	—	1	—
8 36 32 ,,	—	1	33
8 37 11 ,,	—	1	—
8 37 35 ,,	—	1	26
8 38 03 ,,	—	1	25
8 38 29 ,,	—	1	—
8 38 53 ,,	—	1	30
8 40 54 ,,	—	1	—

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(1) Two unfelt A-type shocks, or volcanic earthquakes not accompanied by eruption, took place respectively at 4.56.22 a.m., on Aug. 1st, and at 8.28.46 am., on Aug. 2nd, their elements of motion being as follows:—
1st eqke: dur. prel. tremor = 0.3 sec., total dur. = 14 sec., longit. max. 2a. = 23μ.
2nd eqke: dur. prel. tremor = 0.4 sec., tolal dur. = 24 sec., longit. max. 2a. = 64μ.

On Aug. 3rd, the Asama was emitting black smokes almost continuously with force.

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 3	sec.	μ	sec.	**AUG. 3**	sec.	μ	sec.
8 41 48 p.m.	—	1	—	10 15 09 p.m.	—	1	—
8 42 38 ,,	—	1	—	10 15 37 ,,	—	1	—
8 44 32 ,,	—	1	15	10 16 08 ,,	—	1	—
8 45 18 ,,	—	1	30	10 16 51 ,,	—	1	—
8 46 10 ,,	—	1	16	10 17 22 ,,	—	1	—
9 19 13 ,,	—	1	—	10 18 45 ,,	—	1	—
9 19 43 ,,	—	1	—	10 19 04 ,,	—	1	—
9 20 01 ,,	—	1	—	10 19 20 ,,	—	1	—
9 20 46 ,,	—	1	—	10 19 35 ,,	—	1	—
9 21 25 ,,	—	1	—	10 24 26 ,,	—	1	—
9 21 57 ,,	—	1	—	10 25 45 ,,	—	1	—
9 22 29 ,,	—	1	25	10 26 19 ,,	—	1	—
9 23 32 ,,	—	1	—	10 26 44 ,,	—	1	—
9 24 14 ,,	—	1	—	10 27 14 ,,	—	1	20
9 24 55 ,,	—	1	—	10 27 43 ,,	—	1	24
9 38 14 ,,	—	1	—	10 28 46 ,,	—	1	20
9 38 34 ,,	—	1	28	10 29 19 ,,	—	1	19
9 39 18 ,,	—	1	—	10 31 06 ,,	—	1	—
9 39 57 ,,	—	1	—	10 31 53 ,,	—	1	35
9 45 05 ,,	—	1	28	10 33 53 ,,	—	1	—
9 47 01 ,,	—	1	46	10 35 30 ,,	—	1	—
9 57 20 ,,	—	1	—	10 36 17 ,,	—	1	—
9 58 18 ,,	—	1	—	10 37 17 ,,	—	1	49
9 59 15 ,,	—	1	—	10 38 14 ,,	—	1	31
9 59 57 ,,	—	1	28	10 38 54 ,,	—	1	15
10 00 36 ,,	—	1	—	10 39 23 ,,	—	1	—
10 01 27 ,,	—	1	44	10 40 00 ,,	—	1	18
10 03 01 ,,	—	1	54	10 40 29 ,,	—	1	—
10 06 58 ,,	—	1	—	10 41 26 ,,	—	1	—
10 08 28 ,,	—	1	—	10 41 41 ,,	—	1	—
10 08 56 ,,	—	1	—	10 42 05 ,,	—	1	—
10 09 54 ,,	—	1	—	10 42 20 ,,	—	1	—
10 10 42 ,,	—	1	—	10 42 51 ,,	—	1	29
10 11 35 ,,	—	1	—	10 43 28 ,,	—	1	—
10 11 44 ,,	—	1	—	10 43 46 ,,	—	1	—
10 12 16 ,,	—	1	—	10 44 25 ,,	—	1	—
10 12 42 ,,	—	1	—	10 44 51 ,,	—	1	—
10 13 01 ,,	—	1	—	10 45 33 ,,	—	1	—
10 13 27 ,,	—	1	—	10 46 03 ,,	—	1	—
10 14 26 ,,	—	1	—	10 46 31 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 3	sec.	μ	sec.	**AUG. 3**	sec.	μ	sec.
10 46 56 p.m.	—	1	—	11 08 06 p.m.	—	1	—
10 47 36 „	—	1	—	11 08 34 „	—	1	—
10 48 03 „	—	1	—	11 09 32 „	—	1	—
10 48 24 „	—	1	—	11 10 14 „	—	1	—
10 48 49 „	—	1	—	11 10 37 „	—	1	—
10 49 19 „	—	1	—	11 11 28 „	—	1	—
10 49 46 „	—	1	—	11 12 15 „	—	1	—
10 50 24 „	—	1	—	11 13 17 „	—	1	—
10 50 47 „	—	1	—	11 13 50 „	—	1	—
10 51 03 „	—	1	—	11 14 23 „	—	1	27
10 51 47 „	—	1	—	11 14 53 „	—	1	—
10 52 42 „	—	1	—	11 15 20 „	—	1	—
10 53 01 „	—	1	—	11 15 45 „	—	1	—
10 53 41 „	—	1	—	11 16 07 „	—	1	—
10 54 21 „	—	1	—	11 16 46 „	—	1	—
10 54 59 „	—	1	—	11 17 22 „	—	1	—
10 55 34 „	—	1	—	11 17 57 „	—	1	—
10 55 54 „	—	1	—	11 18 32 „	—	1	—
10 56 11 „	—	1	—	11 19 19 „	—	1	12
10 56 29 „	—	1	—	11 19 51 „	—	1	—
10 58 01 „	—	1	—	11 20 09 „	—	1	—
10 58 26 „	—	1	—	11 20 47 „	—	1	—
10 58 48 „	—	1	—	11 21 07 „	—	1	—
10 59 15 „	—	1	—	11 21 26 „	—	1	—
10 59 38 „	—	1	—	11 22 14 „	—	1	16
11 00 07 „	—	1	27	11 23 15 „	—	1	—
11 00 40 „	—	1	—	11 24 01 „	—	1	—
11 01 13 „	—	1	—	11 24 50 „	—	1	—
11 01 51 „	—	1	—	11 25 06 „	—	1	—
11 02 29 „	—	1	—	11 25 47 „	—	1	—
11 02 43 „	—	1	—	11 26 22 „	—	1	—
11 03 15 „	—	1	—	11 26 38 „	—	1	—
11 03 47 „	—	1	—	11 27 20 „	—	1	—
11 04 02 „	—	1	—	11 27 45 „	—	1	—
11 04 15 „	—	1	—	11 28 37 „	—	1	—
11 04 41 „	—	1	—	11 29 19 „	—	1	—
11 05 09 „	—	1	—	11 29 37 „	—	1	—
11 05 44 „	—	1	—	11 33 30 „	—	1	—
11 06 57 „	—	1	—	11 33 59 „	—	1	—
11 07 30 „	—	1	—	11 34 42 „	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 3	sec.	μ	sec.	AUG. 3	sec.	μ	sec.
11 34 58 p.m.	—	1	—	11 56 20 p.m.	—	1	—
11 35 24 „	—	1	—	11 56 56 „	—	1	—
11 35 48 „	—	1	—	11 57 33 „	—	1	—
11 36 14 „	—	1	12	11 57 49 „	—	1	—
11 36 40 „	—	1	—	11 58 12 „	—	1	—
11 36 55 „	—	1	—	11 58 30 „	—	1	—
11 37 30 „	—	1	—	11 59 11 „	—	1	—
11 37 57 „	—	1	—	11 59 37 „	—	1	—
11 38 15 „	—	1	—	AUG. 4	—		—
11 38 48 „	—	1	—	0 00 21 a.m.	—	1	—
11 39 38 „	—	1	—	0 01 01 „	—	1	—
11 39 56 „	—	1	—	0 01 36 „	—	1	—
11 40 30 „	—	1	—	0 01 50 „	—	1	—
11 41 00 „	—	1	—	0 02 25 „	—	1	—
11 41 42 „	—	1	—	0 02 54 „	—	1	—
11 42 09 „	—	1	—	0 03 46 „	—	1	—
11 42 45 „	—	1	—	0 04 32 „	—	1	—
11 44 00 „	—	1	—	0 05 02 „	—	1	—
11 44 25 „	—	1	—	0 05 34 „	—	1	—
11 45 09 „	—	1	—	0 06 01 „	—	1	—
11 46 13 „	—	1	—	0 06 26 „	—	1	—
11 47 02 „	—	1	—	0 06 46 „	—	1	—
11 47 43 „	—	1	—	0 07 57 „	—	1	—
11 48 12 „	—	1	—	0 08 27 „	—	1	—
11 48 41 „	—	1	—	0 08 54 „	—	1	—
11 49 22 „	—	1	—	0 09 16 „	—	1	—
11 50 28 „	—	1	—	0 09 32 „	—	1	—
11 50 47 „	—	1	—	0 10 01 „	—	1	—
11 51 17 „	—	1	—	0 10 31 „	—	1	—
11 51 49 „	—	1	—	0 10 56 „	—	1	—
11 52 10 „	—	1	—	0 11 20 „	—	1	—
11 52 37 „	—	1	—	0 12 04 „	—	1	—
11 53 10 „	—	1	—	0 12 26 „	—	1	—
11 53 41 „	—	1	—	0 13 15 „	—	1	—
11 53 51 „	—	1	—	0 13 44 „	—	1	—
11 54 09 „	—	1	—	0 14 02 „	—	1	18
11 54 27 „	—	1	—	0 14 39 „	—	1	—
11 55 03 „	—	1	—	0 15 00 „	—	1	—
11 55 26 „	—	1	—	0 15 45 „	—	1	—
11 55 56 „	—	1	—	0 16 15 „	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 4	sec.	μ	sec.	AUG. 4	sec.	μ	sec.
0 16 28 a.m.	—	1	—	0 43 36 a.m.	—	1	—
0 17 00 ,,	—	1	—	0 44 04 ,,	—	1	—
0 17 31 ,,	—	1	—	0 44 30 ,,	—	1	—
0 17 44 ,,	—	1	—	0 45 21 ,,	—	1	—
0 18 02 ,,	—	1	—	0 45 54 ,,	—	1	—
0 18 39 ,,	—	1	23	0 46 23 ,,	—	1	14
0 19 09 ,,	—	1	36	0 46 44 ,,	—	1	—
0 19 58 ,,	—	1	—	0 47 32 ,,	—	1	—
0 20 31 ,,	—	1	20	0 47 59 ,,	—	1	—
0 20 52 ,,	—	1	—	0 49 23 ,,	—	1	28
0 21 21 ,,	—	1	31	0 50 05 ,,	—	1	—
0 21 59 ,,	—	1	17	0 50 37 ,,	—	1	18
0 22 59 ,,	—	1	—	0 51 58 ,,	—	1	—
0 23 47 ,,	—	1	35	0 52 14 ,,	—	1	41
0 25 24 ,,	—	1	—	0 53 08 ,,	—	1	21
0 25 51 ,,	—	1	18	0 53 42 ,,	—	1	—
0 28 16 ,,	—	1	—	0 54 11 ,,	—	1	18
0 28 58 ,,	—	1	18	0 54 55 ,,	—	1	34
0 29 56 ,,	—	1	16	1 00 17 ,,	—	1	38
0 30 45 ,,	—	1	—	1 01 05 ,,	—	1	20
0 31 03 ,,	—	1	—	1 01 44 ,,	—	1	35
0 31 21 ,,	—	1	—	1 02 55 ,,	—	1	11
0 31 56 ,,	—	1	—	1 03 14 ,,	—	1	—
0 32 34 ,,	—	1	—	1 03 57 ,,	—	1	—
0 32 52 ,,	—	1	—	1 04 27 ,,	—	1	—
0 33 40 ,,	—	1	—	1 05 09 ,,	—	1	—
0 34 20 ,,	—	1	—	1 08 11 ,,	—	1	—
0 34 36 ,,	—	1	—	1 12 52 ,,	—	1	—
0 35 31 ,,	—	1	—	1 13 14 ,,	—	1	—
0 35 56 ,,	—	1	—	1 13 45 ,,	—	1	—
0 36 41 ,,	—	1	—	1 14 18 ,,	—	1	—
0 37 10 ,,	—	1	—	1 14 50 ,,	—	1	—
0 37 41 ,,	—	1	—	1 15 19 ,,	—	1	—
0 38 37 ,,	—	1	—	1 15 55 ,,	—	1	—
0 39 06 ,,	—	1	29	1 17 18 ,,	—	1	—
0 39 54 ,,	—	1	43	1 18 11 ,,	3.4	1	—
0 40 44 ,,	—	1	—	1 18 45 ,,	—	1	—
0 41 07 ,,	—	1	—	1 19 09 ,,	—	1	—
0 41 27 ,,	—	1	—	1 21 15 ,,	—	1	—
0 42 54 ,,	—	1	—	1 21 52 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 4	sec.	μ	sec.
1 22 03 a.m.	—	1	—
1 22 19 ,,	—	1	—
1 22 28 ,,	—	1	—
1 23 13 ,,	—	1	—
1 23 41 ,,	—	1	—
1 24 27 ,,	—	1	—
1 25 14 ,,	—	1	—
1 26 30 ,,	—	1	—
1 27 04 ,,	—	1	—
1 27 59 ,,	—	1	29
1 28 48 ,,	—	1	—
1 29 53 ,,	—	1	22
1 30 54 ,,	—	1	36
1 31 49 ,,	—	1	40
1 33 08 ,,	—	1	—
1 34 10 ,,	—	1	—
1 34 47 ,,	—	1	—
1 35 16 ,,	—	1	24
1 35 59 ,,	—	1	—
1 36 40 ,,	—	1	—
1 37 04 ,,	—	1	—
1 37 49 ,,	—	1	—
1 38 45 ,,	—	1	22
1 39 12 ,,	—	1	—
1 39 59 ,,	—	1	—
1 40 43 ,,	—	1	—
1 41 14 ,,	—	1	—
1 41 56 ,,	—	1	—
1 43 08 ,,	—	1	—
1 44 08 ,,	—	1	—
1 44 35 ,,	—	1	—
1 45 24 ,,	—	1	—
1 46 12 ,,	—	1	—
1 46 38 ,,	—	1	—
1 47 15 ,,	—	1	—
1 47 54 ,,	—	1	—
1 48 43 ,,	—	1	31
1 50 43 ,,	—	1	51
1 52 50 ,,	—	1	18
1 53 20 ,,	—	1	—
1 53 58 a.m.	—	1	—
1 54 17 ,,	—	1	—
1 54 40 ,,	—	1	—
1 55 11 ,,	—	1	—
1 55 42 ,,	—	1	—
1 56 06 ,,	—	1	—
1 56 21 ,,	—	1	—
1 56 51 ,,	—	1	—
1 57 09 ,,	—	1	—
1 57 30 ,,	—	1	—
1 57 58 ,,	—	1	—
1 58 26 ,,	—	1	—
1 59 06 ,,	—	1	—
1 59 34 ,,	—	1	—
2 00 11 ,,	—	1	—
2 01 10 ,,	—	1	—
2 01 35 ,,	—	1	—
2 02 26 ,,	—	1	—
2 03 01 ,,	—	1	—
2 03 34 ,,	—	1	—
2 03 57 ,,	—	1	—
2 04 37 ,,	—	1	—
2 05 15 ,,	—	1	—
2 05 50 ,,	—	1	—
2 06 31 ,,	—	1	—
2 06 58 ,,	—	1	—
2 07 34 ,,	—	1	—
2 07 54 ,,	—	1	—
2 08 16 ,,	—	1	—
2 08 38 ,,	—	1	—
2 08 57 ,,	—	1	—
2 09 28 ,,	—	1	—
2 09 47 ,,	—	1	—
2 10 11 ,,	—	1	—
2 10 29 ,,	—	1	—
2 10 50 ,,	—	1	—
2 11 23 ,,	—	1	—
2 11 46 ,,	—	1	—
2 12 20 ,,	—	1	—
2 12 41 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 4	sec.	μ	sec.	**AUG. 4**	sec.	μ	sec.
2 13 08 a.m.	—	1	—	2 34 39 a.m.	—	1	—
2 13 43 ,,	—	1	—	2 35 00 ,,	—	1	—
2 13 58 ,,	—	1	—	2 35 44 ,,	—	1	—
2 14 27 ,,	—	1	—	2 36 15 ,,	—	1	—
2 14 52 ,,	—	1	—	2 36 50 ,,	—	1	41
2 15 13 ,,	—	1	—	2 37 47 ,,	—	1	—
2 15 55 ,,	—	1	—	2 37 59 ,,	—	1	—
2 16 39 ,,	—	1	—	2 38 24 ,,	—	1	—
2 17 20 ,,	—	1	—	2 38 50 ,,	—	1	—
2 18 03 ,,	—	1	21	2 39 24 ,,	—	1	—
2 19 01 ,,	—	1	—	2 39 58 ,,	—	1	—
2 19 27 ,,	—	1	—	2 40 25 ,,	—	1	—
2 20 06 ,,	—	1	—	2 41 17 ,,	—	1	—
2 20 28 ,,	—	1	—	2 41 55 ,,	—	1	33
2 21 02 ,,	—	1	—	2 42 45 ,,	—	1	17
2 21 36 ,,	—	1	—	2 43 17 ,,	—	1	—
2 22 13 ,,	—	1	—	2 43 50 ,,	—	1	13
2 22 43 ,,	—	1	—	2 44 09 ,,	—	1	—
2 23 13 ,,	—	1	40	2 44 31 ,,	—	1	—
2 24 05 ,,	—	1	—	2 45 13 ,,	—	1	—
2 24 39 ,,	—	1	—	2 46 04 ,,	—	1	—
2 25 16 ,,	—	1	28	2 46 30 ,,	—	1	—
2 25 59 ,,	—	1	—	2 46 45 ,,	—	1	—
2 26 22 ,,	—	1	—	2 47 17 ,,	—	1	—
2 26 49 ,,	—	1	—	2 47 34 ,,	—	1	—
2 27 16 ,,	—	1	—	2 48 06 ,,	—	1	—
2 27 32 ,,	—	1	—	2 48 32 ,,	—	1	—
2 27 47 ,,	—	1	—	2 48 49 ,,	—	1	—
2 28 12 ,,	—	1	—	2 49 19 ,,	—	1	—
2 28 33 ,,	—	1	—	2 49 45 ,,	—	1	—
2 29 05 ,,	—	1	34	2 50 04 ,,	—	1	—
2 29 41 ,,	—	1	—	2 50 36 ,,	—	1	—
2 30 03 ,,	—	1	31	2 51 10 ,,	—	1	—
2 30 45 ,,	—	1	—	2 51 28 ,,	—	1	—
2 31 35 ,,	—	1	—	2 51 53 ,,	—	1	—
2 32 04 ,,	—	1	—	2 52 14 ,,	—	1	—
2 32 38 ,,	—	1	—	2 52 32 ,,	—	1	—
2 33 25 ,,	—	1	—	2 53 14 ,,	—	1	—
2 33 52 ,,	—	1	—	2 53 39 ,,	—	1	—
2 34 15 ,,	—	1	—	2 54 05 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 4	sec.	μ	sec.	**AUG. 4**	sec.	μ	sec.
2 54 27 a.m.	—	1	—	3 13 41 a.m.	—	1	—
2 54 46 ,,	—	1	—	3 14 16 ,,	—	1	—
2 55 07 ,,	—	1	—	3 14 46 ,,	—	1	—
2 55 40 ,,	—	1	—	3 15 15 ,,	—	1	—
2 55 54 ,,	—	1	—	3 15 45 ,,	—	1	—
2 56 17 ,,	—	1	—	3 16 19 ,,	—	1	—
2 56 30 ,,	—	1	—	3 16 46 ,,	—	1	—
2 56 51 ,,	—	1	—	3 17 21 ,,	—	1	—
2 57 21 ,,	—	1	—	3 17 59 ,,	—	1	—
2 57 55 ,,	—	1	—	3 18 16 ,,	—	1	—
2 58 29 ,,	—	1	—	3 18 49 ,,	—	1	—
2 59 16 ,,	—	1	—	3 19 05 ,,	—	1	—
2 59 50 ,,	—	1	—	3 19 24 ,,	—	1	40
3 00 17 ,,	—	1	26	3 20 07 ,,	—	1	—
3 00 53 ,,	—	1	—	3 20 36 ,,	—	1	—
3 01 28 ,,	—	1	—	3 20 54 ,,	—	1	—
3 01 51 ,,	—	1	—	3 21 24 ,,	—	1	—
3 02 13 ,,	—	1	—	3 21 48 ,,	—	1	—
3 02 29 ,,	—	1	—	3 22 07 ,,	—	1	—
3 02 44 ,,	—	1	16	3 22 22 ,,	—	1	—
3 03 28 ,,	—	1	—	3 22 45 ,,	—	1	—
3 03 48 ,,	—	1	—	3 23 02 ,,	—	1	—
3 04 16 ,,	—	1	—	3 23 31 ,,	—	1	—
3 04 37 ,,	—	1	—	3 23 58 ,,	—	1	—
3 05 03 ,,	—	1	—	3 24 17 ,,	—	1	—
3 05 15 ,,	—	1	—	3 24 33 ,,	—	1	—
3 05 43 ,,	—	1	—	3 24 56 ,,	—	1	—
3 06 07 ,,	—	1	12	3 25 16 ,,	—	1	—
3 06 29 ,,	—	1	—	3 25 50 ,,	—	1	21
3 06 59 ,,	—	1	—	3 26 31 ,,	—	1	—
3 07 24 ,,	—	1	—	3 27 11 ,,	—	1	—
3 08 09 ,,	—	1	—	3 27 53 ,,	—	1	19
3 08 43 ,,	—	1	29	3 28 20 ,,	—	1	—
3 09 49 ,,	—	1	16	3 28 39 ,,	—	1	—
3 10 31 ,,	—	1	—	3 29 14 ,,	—	1	—
3 11 12 ,,	—	1	38	3 29 39 ,,	—	1	33
3 11 52 ,,	—	1	19	3 30 23 ,,	—	1	—
3 12 22 ,,	—	1	17	3 31 02 ,,	—	1	34
3 12 46 ,,	—	1	—	3 31 43 ,,	—	1	16
3 13 12 ,,	—	1	—	3 32 09 ,,	—	1	29

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 4	sec.	μ	sec.	AUG. 4	sec.	μ	sec.
3 33 38 a.m.	—	1	31	3 57 54 a.m.	—	1	—
3 34 21 ,,	—	1	—	3 58 07 ,,	—	1	—
3 34 50 ,,	—	1	21	3 58 30 ,,	—	1	—
3 35 20 ,,	—	1	32	3 58 49 ,,	—	1	—
3 36 05 ,,	—	1	19	3 59 09 ,,	—	1	—
3 36 32 ,,	—	1	27	3 59 28 ,,	—	1	—
3 37 20 ,,	—	1	19	3 59 49 ,,	—	1	—
3 38 54 ,,	—	1	—	4 00 10 ,,	—	1	—
3 39 17 ,,	—	1	34	4 00 28 ,,	—	1	—
3 40 20 ,,	—	1	—	4 00 50 ,,	—	1	—
3 40 42 ,,	—	1	—	4 01 31 ,,	—	1	—
3 41 03 ,,	—	1	—	4 02 02 ,,	—	1	—
3 41 30 ,,	—	1	—	4 02 23 ,,	—	1	—
3 42 13 ,,	—	1	—	4 02 54 ,,	—	1	—
3 42 46 ,,	—	1	31	4 03 34 ,,	—	1	29
3 43 40 ,,	—	1	—	4 04 09 ,,	—	1	—
3 44 30 ,,	—	1	—	4 04 53 ,,	—	1	—
3 44 53 ,,	—	1	—	4 05 27 ,,	—	1	—
3 45 29 ,,	—	1	—	4 05 57 ,,	—	1	—
3 45 46 ,,	—	1	—	4 06 49 ,,	—	1	—
3 46 16 ,,	—	1	—	4 07 08 ,,	—	1	—
3 46 54 ,,	—	1	—	4 07 26 ,,	—	1	—
3 48 06 ,,	—	1	—	4 07 41 ,,	—	1	—
3 48 32 ,,	—	1	—	4 07 59 ,,	—	1	—
3 49 15 ,,	—	1	—	4 08 17 ,,	—	1	—
3 49 48 ,,	—	1	—	4 08 36 ,,	—	1	—
3 50 35 ,,	—	1	—	4 08 55 ,,	—	1	—
3 51 14 ,,	—	1	—	4 09 21 ,,	—	1	—
3 51 43 ,,	—	1	—	4 09 40 ,,	—	1	—
3 52 24 ,,	—	1	—	4 09 56 ,,	—	1	—
3 53 03 ,,	—	1	—	4 10 20 ,,	—	1	—
3 53 27 ,,	—	1	34	4 10 45 ,,	—	1	—
3 54 09 ,,	—	1	—	4 11 19 ,,	—	1	—
3 54 41 ,,	—	1	—	4 11 45 ,,	—	1	—
3 55 11 ,,	—	1	—	4 12 07 ,,	—	1	—
3 55 33 ,,	—	1	—	4 12 21 ,,	—	1	—
3 56 14 ,,	—	1	—	4 12 52 ,,	—	1	—
3 56 45 ,,	—	1	—	4 13 17 ,,	—	1	—
3 57 06 ,,	—	1	—	4 13 39 ,,	—	1	—
3 57 34 ,,	—	1	—	4 14 18 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 4	sec.	μ	sec.	**AUG. 4**	sec.	μ	sec.
4 14 43 a.m.	—	1	—	4 38 59 a.m.	—	1	15
4 15 07 ,,	—	1	—	4 39 48 ,,	—	1	22
4 15 25 ,,	—	1	—	4 41 11 ,,	—	1	—
4 15 43 ,,	—	1	—	4 42 01 ,,	—	1	21
4 16 03 ,,	—	1	—	4 42 45 ,,	—	1	23
4 16 24 ,,	—	1	—	4 43 12 ,,	—	1	22
4 16 43 ,,	—	1	—	4 43 57 ,,	—	1	—
4 17 02 ,,	—	1	—	4 49 49 ,,	—	1	18
4 17 27 ,,	—	1	—	4 50 41 ,,	—	1	32
4 17 47 ,,	—	1	—	4 51 56 ,,	—	1	23
4 18 23 ,,	—	1	—	4 52 35 ,,	—	1	—
4 18 57 ,,	—	1	—	4 53 29 ,,	—	1	—
4 19 14 ,,	—	1	18	4 54 26 ,,	—	1	—
4 19 52 ,,	—	1	16	4 56 08 ,,	—	1	20
4 20 25 ,,	—	1	—	4 59 17 ,,	—	1	24
4 20 51 ,,	—	1	—	5 00 32 ,,	—	1	—
4 21 23 ,,	—	1	—	5 01 48 ,,	—	1	—
4 21 49 ,,	—	1	—	5 02 34 ,,	—	1	—
4 22 19 ,,	—	1	14	5 04 47 ,,	—	1	28
4 23 04 ,,	—	1	—	5 06 54 ,,	—	1	54
4 23 23 ,,	—	1	—	5 08 01 ,,	—	1	—
4 23 48 ,,	—	1	—	5 09 41 ,,	—	1	—
4 24 29 ,,	—	1	—	5 10 30 ,,	—	1	—
4 25 08 ,,	—	1	20	5 11 01 ,,	—	1	—
4 27 04 ,,	—	1	38	5 11 43 ,,	—	1	—
4 29 05 ,,	—	1	—	5 12 57 ,,	—	1	—
4 29 18 ,,	—	1	—	5 14 23 ,,	—	1	—
4 29 39 ,,	—	1	—	5 15 41 ,,	—	1	—
4 30 12 ,,	—	1	31	5 16 20 ,,	—	1	—
4 30 52 ,,	—	1	—	5 17 18 ,,	—	1	—
4 31 22 ,,	—	1	—	5 18 31 ,,	—	1	—
4 31 45 ,,	—	1	—	5 19 23 ,,	—	1	—
4 32 07 ,,	—	1	—	5 20 01 ,,	—	1	23
4 32 47 ,,	—	1	22	5 20 30 ,,	—	1	—
4 33 28 ,,	—	1	33	5 21 24 ,,	—	1	—
4 34 47 ,,	—	1	30	5 21 51 ,,	—	1	—
4 35 51 ,,	—	1	—	5 22 26 ,,	—	1	—
4 36 30 ,,	—	1	28	5 22 55 ,,	—	1	—
4 37 18 ,,	—	1	23	5 23 32 ,,	—	1	—
4 38 26 ,,	—	1	23	5 24 54 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 4	sec.	μ	sec.	AUG. 4	sec.	μ	sec.
5 25 11 a.m.	—	1	33	5 49 39 a.m.	—	1	—
5 26 05 ,,	—	1	—	5 50 04 ,,	—	1	—
5 26 46 ,,	—	1	—	5 50 40 ,,	—	1	—
5 27 34 ,,	—	1	—	5 51 12 ,,	—	1	—
5 28 25 ,,	—	1	—	5 51 42 ,,	—	1	—
5 29 00 ,,	—	1	—	5 51 58 ,,	—	1	—
5 29 37 ,,	—	1	18	5 52 31 ,,	—	1	—
5 30 15 ,,	—	1	—	5 53 09 ,,	—	1	—
5 31 18 ,,	—	1	—	5 53 39 ,,	—	1	—
5 32 00 ,,	—	1	33	5 53 53 ,,	—	1	—
5 33 03 ,,	—	1	—	5 54 24 ,,	—	1	—
5 33 27 ,,	—	1	—	5 54 57 ,,	—	1	—
5 33 59 ,,	—	1	—	5 55 18 ,,	—	1	—
5 34 22 ,,	—	1	20	5 55 54 ,,	—	1	—
5 35 10 ,,	—	1	—	5 56 11 ,,	—	1	—
5 35 46 ,,	—	1	—	5 56 34 ,,	—	1	—
5 36 07 ,,	—	1	—	5 57 00 ,,	—	1	—
5 36 56 ,,	—	1	—	5 57 29 ,,	—	1	—
5 37 39 ,,	—	1	—	5 57 58 ,,	—	1	—
5 38 11 ,,	—	1	—	5 58 32 ,,	—	1	—
5 38 36 ,,	—	1	—	5 58 53 ,,	—	1	—
5 39 23 ,,	—	1	—	5 59 11 ,,	—	1	—
5 39 58 ,,	—	1	—	6 00 02 ,,	—	1	—
5 40 14 ,,	—	1	—	6 00 17 ,,	—	1	—
5 40 33 ,,	—	1	—	6 01 00 ,,	—	1	—
5 41 15 ,,	—	1	—	6 02 15 ,,	—	1	43
5 41 35 ,,	—	1	—	6 02 59 ,,	—	1	21
5 41 55 ,,	—	1	—	6 03 40 ,,	—	1	39
5 42 28 ,,	—	1	—	6 04 35 ,,	—	1	—
5 43 26 ,,	—	1	—	6 05 17 ,,	—	1	—
5 43 51 ,,	—	1	—	6 05 46 ,,	—	1	—
5 44 18 ,,	—	1	—	6 06 12 ,,	—	1	—
5 44 59 ,,	—	1	—	6 06 49 ,,	—	1	—
5 45 31 ,,	—	1	—	6 07 37 ,,	—	1	—
5 46 17 ,,	—	1	—	6 09 05 ,,	—	1	—
5 46 47 ,,	—	1	—	6 09 39 ,,	—	1	—
5 47 39 ,,	—	1	—	6 09 58 ,,	—	1	—
5 48 13 ,,	—	1	—	6 10 23 ,,	—	1	—
5 48 50 ,,	—	1	—	6 11 03 ,,	—	1	—
5 49 14 ,,	—	1	—	6 14 26 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 4	sec.	μ	sec.
6 15 03 a.m.	—	1	—
6 15 25 ,,	—	1	—
6 15 54 ,,	—	1	—
6 16 29 ,,	—	1	—
6 16 59 ,,	—	1	—
6 19 47 ,,	—	1	—
6 23 47 ,,	—	1	23
6 24 26 ,,	—	1	47
6 25 40 ,,	—	1	—
6 26 09 ,,	—	1	22
6 26 36 ,,	—	1	—
6 26 45 ,,	—	1	—
6 27 09 ,,	—	1	—
6 28 13 ,,	—	1	30
6 28 56 ,,	—	1	—
6 29 26 ,,	—	1	40
6 30 25 ,,	—	1	—
6 31 12 ,,	—	1	27
6 32 13 ,,	—	1	60
6 36 49 ,,	—	1	41
6 38 21 ,,	—	1	—
6 44 27 ,,	—	1	—
6 44 42 ,,	—	1	—
6 45 34 ,,	—	1	—
6 46 09 ,,	—	1	—
6 46 31 ,,	—	1	—
6 47 57 ,,	—	1	—
6 49 40 ,,	—	1	—
6 49 51 ,,	—	1	—
6 50 18 ,,	—	1	—
6 50 31 ,,	—	1	—
6 50 53 ,,	—	1	—
6 51 42 ,,	—	1	—
6 52 10 ,,	—	1	31
6 52 53 ,,	—	1	—
6 53 20 ,,	—	1	—
6 54 07 ,,	—	1	—
6 54 36 ,,	—	1	—
6 56 08 ,,	—	1	26
6 57 17 ,,	—	1	18
AUG. 4	sec.	μ	sec.
6 57 36 a.m.	—	1	—
6 59 47 ,,	—	1	11
7 00 48 ,,	—	1	—
7 06 07 ,,	—	1	—
7 26 02 ,,	—	1	—
7 26 31 ,,	—	1	—
7 27 16 ,,	—	1	—
7 29 34 ,,	—	1	—
7 29 48 ,,	—	1	—
7 30 04 ,,	—	1	—
7 30 15 ,,	—	1	—
7 30 54 ,,	—	1	—
7 31 10 ,,	2.2	1	16
7 31 36 ,,	—	1	—
7 31 51 ,,	—	1	—
7 32 03 ,,	—	1	—
7 32 25 ,,	—	1	—
7 32 52 ,,	—	2	—
7 33 24 ,,	—	1	—
7 33 51 ,,	—	1	—
7 34 28 ,,	—	1	—
7 35 04 ,,	—	1	—
7 36 26 ,,	—	1	28
7 37 42 ,,	—	1	15
7 38 27 ,,	—	1	23
7 39 19 ,,	—	1	20
7 42 31 ,,	—	1	14
7 44 10 ,,	—	1	17
7 46 16 ,,	—	1	—
7 46 43 ,,	—	1	—
7 46 51 ,,	—	1	—
7 47 12 ,,	—	1	—
7 47 25 ,,	—	1	—
7 47 42 ,,	—	1	—
7 48 04 ,,	—	1	—
7 48 20 ,,	—	1	—
7 48 35 ,,	—	1	—
7 48 53 ,,	—	1	—
7 49 19 ,,	—	1	—
7 49 38 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 4	sec.	μ	sec.	**AUG. 4**	sec.	μ	sec.
7 49 48 a.m.	—	1	—	8 12 54 a.m.	—	1	—
7 50 09 „	—	1	—	8 13 14 „	—	1	16
7 50 20 „	—	1	—	8 13 39 „	—	1	—
7 50 33 „	—	1	—	8 14 05 „	—	1	—
7 51 03 „	—	1	—	8 14 39 „	—	1	—
7 51 23 „	—	1	—	8 15 19 „	—	1	—
7 51 50 „	—	1	—	8 15 33 „	—	1	16
7 52 03 „	—	1	—	8 15 55 „	—	1	—
7 52 18 „	—	1	—	8 16 09 „	—	1	16
7 52 40 „	—	1	—	8 17 43 „	—	1	16
7 52 55 „	—	1	—	8 18 02 „	—	1	—
7 53 11 „	—	1	—	8 18 25 „	—	1	17
7 53 23 „	—	1	—	8 19 30 „	—	1	26
7 53 41 „	—	1	—	8 22 58 „	—	1	20
7 53 57 „	—	1	—	8 23 29 „	—	1	—
7 54 08 „	—	1	—	8 23 38 „	—	1	—
7 54 20 „	—	1	—	8 23 59 „	—	1	14
7 54 49 „	—	1	—	8 24 43 „	—	1	21
7 55 14 „	—	1	—	8 26 11 „	—	1	30
7 55 59 „	—	1	—	8 27 20 „	—	1	24
7 56 42 „	—	1	—	8 27 52 „	—	1	—
7 57 01 „	—	1	—	8 28 11 „	—	1	13
7 57 26 „	—	1	—	8 28 58 „	—	1	16
8 00 06 „	—	1	—	8 29 17 „	—	1	16
8 00 38 „	—	1	—	8 30 18 „	—	1	34
8 01 26 „	—	1	29	8 31 06 „	—	1	—
8 02 04 „	—	1	—	8 31 18 „	—	1	14
8 02 44 „	—	1	36	8 31 45 „	—	1	—
8 04 42 „	—	1	30	8 32 02 „	—	1	—
8 07 45 „	—	1	18	8 32 19 „	—	1	32
8 08 06 „	—	1	—	8 35 47 „	—	1	—
8 08 41 „	—	1	29	8 36 17 „	—	1	—
8 09 28 „	—	1	—	8 36 30 „	—	1	17
8 10 32 „	—	1	—	8 37 15 „	—	1	20
8 10 47 „	—	1	—	8 38 51 „	—	1	17
8 11 04 „	—	1	—	8 39 17 „	—	1	21
8 11 25 „	—	1	—	8 39 49 „	—	1	—
8 11 45 „	—	1	—	8 40 18 „	—	1	—
8 11 56 „	—	1	—	8 41 06 „	—	1	—
8 12 25 „	—	1	—	8 41 56 „	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 4	sec.	μ	sec.	**AUG. 4**	sec.	μ	sec.
8 42 11 a.m.	—	1	—	9 21 38 a.m.	—	1	21
8 42 31 ,,	—	1	—	9 23 24 ,,	—	1	—
8 42 52 ,,	—	1	—	9 25 07 ,,	—	1	—
8 43 12 ,,	—	1	—	9 25 51 ,,	—	1	—
8 43 33 ,,	—	1	—	9 28 18 ,,	—	1	—
8 43 49 ,,	—	1	—	9 36 35 ,,	—	1	—
8 44 11 ,,	—	1	—	9 36 51 ,,	—	1	—
8 44 29 ,,	—	1	—	9 37 30 ,,	—	1	—
8 45 00 ,,	—	1	—	9 38 06 ,,	—	1	—
8 45 11 ,,	—	1	—	9 38 26 ,,	—	1	—
8 45 27 ,,	—	1	—	9 38 38 ,,	—	1	—
8 46 08 ,,	—	1	—	9 38 54 ,,	—	1	—
8 46 40 ,,	—	1	28	9 39 42 ,,	—	1	—
8 47 27 ,,	—	1	—	9 39 50 ,,	—	1	—
8 49 58 ,,	—	1	33	9 40 06 ,,	—	1	—
8 50 53 ,,	—	1	—	9 40 23 ,,	—	1	—
8 51 22 ,,	—	1	—	9 40 49 ,,	—	1	—
8 52 12 ,,	—	1	—	9 41 06 ,,	—	1	—
8 52 32 ,,	—	1	—	9 41 24 ,,	—	1	—
8 53 00 ,,	—	1	—	9 41 46 ,,	—	1	—
8 53 45 ,,	—	1	—	9 42 01 ,,	—	1	—
8 54 10 ,,	—	1	—	9 42 43 ,,	—	1	—
8 54 37 ,,	—	1	—	9 42 58 ,,	—	1	—
8 57 17 ,,	—	1	14	9 43 11 ,,	—	1	—
8 57 54 ,,	—	1	16	9 43 30 ,,	—	1	—
9 00 05 ,,	—	1	17	9 43 48 ,,	—	1	—
9 00 40 ,,	—	1	20	9 44 09 ,,	—	1	—
9 01 56 ,,	—	1	—	9 44 34 ,,	—	1	—
9 02 13 ,,	—	1	—	9 44 52 ,,	—	1	—
9 03 50 ,,	—	1	34	9 45 14 ,,	—	1	—
9 05 33 ,,	—	1	14	9 45 25 ,,	—	1	—
9 07 23 ,,	—	1	18	9 45 44 ,,	—	1	—
9 08 34 ,,	—	1	34	9 46 04 ,,	—	1	—
9 11 41 ,,	—	1	29	9 46 23 ,,	—	1	29
9 12 16 ,,	—	1	—	9 47 04 ,,	—	1	23
9 14 36 ,,	—	1	12	9 47 38 ,,	—	1	—
9 15 30 ,,	—	1	18	9 47 58 ,,	—	1	—
9 16 04 ,,	—	1	—	9 48 24 ,,	—	1	—
9 18 07 ,,	—	1	16	9 48 42 ,,	—	1	—
9 19 58 ,,	—	1	14	9 48 58 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 4	sec.	μ	sec.	AUG. 4	sec.	μ	sec.
9 52 10 a.m.	—	1	—	10 34 05 a.m.	—	1	26
9 54 05 ,,	—	1	—	10 34 47 ,,	—	1	—
9 54 21 ,,	—	1	—	10 35 13 ,,	—	1	—
9 54 44 ,,	—	1	20	10 37 05 ,,	—	1	—
9 55 15 ,,	—	1	18	10 37 34 ,,	—	1	16
9 55 44 ,,	—	1	18	10 44 24 ,,	—	1	39
9 56 07 ,,	—	1	—	10 45 13 ,,	—	1	21
9 56 34 ,,	—	1	—	10 46 09 ,,	4.5	3	23
9 57 02 ,,	—	1	—	10 56 09 ,,	—	1	—
9 57 10 ,,	—	1	17	10 56 30 ,,	—	1	29
9 57 32 ,,	—	1	16	10 57 37 ,,	—	1	18
9 58 10 ,,	—	1	—	10 58 36 ,,	—	1	—
10 01 23 ,,	—	1	—	11 01 08 ,,	—	1	35
10 01 58 ,,	—	1	—	11 03 12 ,,	—	1	20
10 03 22 ,,	—	1	—	11 37 10 ,,	—	1	17
10 03 37 ,,	—	1	—	0 21 25 p.m.	—	1	20
10 03 54 ,,	—	1	16	2 18 44 ,,	—	1	—
10 04 55 ,,	—	1	20	2 19 05 ,,	—	1	—
10 05 39 ,,	—	1	—	2 19 24 ,,	—	1	—
10 06 50 ,,	—	1	26	2 19 56 ,,	—	1	—
10 11 30 ,,	—	1	—	2 20 24 ,,	—	1	—
10 11 48 ,,	—	1	11	2 20 31 ,,	—	1	—
10 12 31 ,,	—	1	13	2 21 06 ,,	—	1	—
10 13 00 ,,	—	1	18	2 21 29 ,,	—	1	—
10 13 40 ,,	—	1	—	2 21 47 ,,	—	1	—
10 13 50 ,,	—	1	26	2 22 15 ,,	—	1	—
10 15 02 ,,	—	1	23	2 22 35 ,,	—	1	—
10 21 41 ,,	—	1	—	2 22 50 ,,	—	1	—
10 27 47 ,,	—	1	—	2 22 58 ,,	—	1	—
10 28 04 ,,	—	1	—	2 23 22 ,,	—	1	—
10 28 52 ,,	—	1	—	2 23 27 ,,	—	1	—
10 29 46 ,,	—	1	—	2 23 56 ,,	—	1	—
10 29 58 ,,	—	1	—	2 24 09 ,,	—	1	—
10 30 08 ,,	—	1	—	2 24 23 ,,	—	1	—
10 30 32 ,,	—	1	20	2 24 40 ,,	—	1	—
10 31 00 ,,	—	1	18	2 25 02 ,,	—	1	—
10 32 20 ,,	—	1	21	2 25 42 ,,	—	1	—
10 33 00 ,,	—	1	—	2 26 01 ,,	—	1	—
10 33 18 ,,	—	1	20	2 26 16 ,,	—	1	—
10 33 43 ,,	—	1	18	2 26 39 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 4	sec.	μ	sec.
2 26 50 p.m.	—	1	—
2 28 06 ,,	—	1	—
2 28 43 ,,	—	1	—
2 29 12 ,,	—	1	—
2 29 56 ,,	—	1	—
2 30 26 ,,	—	1	—
2 32 50 ,,	—	1	18
2 34 18 ,,	—	1	—
2 34 38 ,,	—	1	—
2 35 17 ,,	—	1	20
2 36 24 ,,	—	1	29
2 44 54 ,,	—	1	20
2 47 13 ,,	—	1	—
2 49 38 ,,	—	1	—
2 50 19 ,,	—	1	—
2 51 08 ,,	—	1	26
2 52 52 ,,	—	1	—
2 53 24 ,,	—	1	—
2 53 57 ,,	—	1	—
2 54 25 ,,	—	1	—
2 55 04 ,,	—	1	—
2 55 23 ,,	—	1	—
2 56 27 ,,	—	1	—
2 57 09 ,,	—	1	—
2 57 31 ,,	—	1	—
2 58 00 ,,	—	1	—
2 58 19 ,,	—	1	—
3 05 52 ,,	—	1	20
3 23 04 ,,	—	1	—
3 26 17 ,,	—	1	18
3 26 47 ,,	—	1	30
3 28 18 ,,	—	1	26
3 29 11 ,,	—	1	20
3 29 39 ,,	—	1	32
3 37 32 ,,	—	1	30
3 38 27 ,,	—	1	—
3 38 55 ,,	—	1	—
7 05 18 ,,	—	1	12
7 20 36 ,,	—	1	14
7 20 51 ,,	—	1	—
AUG. 4	sec.	μ	sec.
7 31 10 p.m.	—	2	17
9 13 08 ,,	—	1	75
9 18 50 ,,	—	1	—
9 19 12 ,,	—	1	—
9 19 26 ,,	—	1	20
9 22 23 ,,	—	1	20
9 27 22 ,,	—	1	—
9 27 32 ,,	—	1	—
9 27 42 ,,	—	1	—
9 28 36 ,,	—	1	—
9 28 52 ,,	—	1	—
9 29 15 ,,	—	1	—
9 29 31 ,,	—	1	18
9 30 12 ,,	—	1	11
9 30 26 ,,	—	1	12
9 30 51 ,,	—	1	—
9 30 57 ,,	—	1	—
9 31 15 ,,	—	1	—
9 31 32 ,,	—	1	17
9 32 32 ,,	—	1	—
9 32 38 ,,	—	1	—
9 32 45 ,,	—	1	12
9 33 48 ,,	—	1	—
9 34 04 ,,	—	1	15
9 34 45 ,,	—	1	—
9 34 56 ,,	—	1	—
9 35 05 ,,	—	1	—
9 35 33 ,,	—	1	12
9 36 05 ,,	—	1	15
9 36 42 ,,	—	1	17
9 37 36 ,,	—	1	11
9 38 33 ,,	—	1	15
9 39 35 ,,	—	1	11
9 40 38 ,,	—	1	14
9 46 42 ,,	—	1	17
9 48 18 ,,	—	1	—
9 48 25 ,,	—	1	—
9 48 36 ,,	—	1	—
9 49 38 ,,	—	1	—
9 49 53 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 4	sec.	μ	sec.	**AUG. 4**	sec.	μ	sec.
9 49 58 p.m.	—	1	—	10 03 19 p.m.	—	1	—
9 50 01 ,,	—	1	—	10 03 38 ,,	—	1	—
9 50 12 ,,	—	1	12	10 03 53 ,,	—	1	—
9 50 28 ,,	—	1	11	10 03 58 ,,	—	1	—
9 50 53 ,,	—	1	—	10 04 20 ,,	—	1	—
9 51 05 ,,	—	1	—	10 04 43 ,,	—	1	—
9 51 12 ,,	—	1	—	10 04 55 ,,	—	1	—
9 51 16 ,,	—	1	—	10 05 16 ,,	—	1	—
9 51 33 ,,	—	1	—	10 05 45 ,,	—	1	—
9 51 41 ,,	—	1	—	10 05 57 ,,	—	1	—
9 51 48 ,,	—	1	—	10 06 23 ,,	—	1	—
9 51 59 ,,	—	1	—	10 06 33 ,,	—	1	—
9 52 06 ,,	—	1	—	10 06 48 ,,	—	1	23
9 52 21 ,,	—	1	—	10 07 40 ,,	—	1	—
9 52 33 ,,	—	1	—	10 07 46 ,,	—	1	—
9 52 37 ,,	—	1	14	10 11 56 ,,	—	1	14
9 53 02 ,,	—	1	—	10 16 18 ,,	—	1	—
9 53 33 ,,	—	1	—	10 16 24 ,,	—	1	—
9 53 37 ,,	—	1	9	10 16 33 ,,	—	1	—
9 53 53 ,,	—	1	14	10 16 38 ,,	—	1	—
9 54 25 ,,	—	1	14	10 16 50 ,,	—	1	—
9 54 55 ,,	—	1	—	10 16 59 ,,	—	1	—
9 55 03 ,,	—	1	—	10 17 08 ,,	—	1	—
9 55 07 ,,	—	1	—	10 17 46 ,,	—	1	14
9 55 25 ,,	—	1	11	10 18 43 ,,	—	1	18
9 55 57 ,,	—	1	14	10 19 52 ,,	—	1	—
9 56 18 ,,	—	1	—	10 19 59 ,,	—	1	—
9 56 26 ,,	—	1	—	10 20 12 ,,	—	1	—
9 56 44 ,,	—	1	—	10 20 43 ,,	—	1	—
9 56 56 ,,	—	1	17	10 20 56 ,,	—	1	19
9 58 25 ,,	—	1	20	10 21 57 ,,	—	1	15
10 00 21 ,,	—	1	—	10 22 33 ,,	—	1	19
10 00 26 ,,	—	1	—	10 23 13 ,,	—	1	—
10 00 58 ,,	—	1	—	10 23 17 ,,	—	1	—
10 01 07 ,,	—	1	—	10 23 48 ,,	—	1	20
10 01 19 ,,	—	1	—	10 25 57 ,,	—	1	22
10 01 22 ,,	—	1	—	10 28 38 ,,	—	1	—
10 01 25 ,,	—	1	—	10 28 58 ,,	—	1	21
10 01 58 ,,	—	1	—	10 29 29 ,,	—	1	22
10 02 40 ,,	—	1	—	10 30 13 ,,	—	1	20

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 4	sec.	μ	sec.	AUG. 4	sec.	μ	sec.
10 30 57 p.m.	—	1	21	10 58 27 p.m.	—	1	21
10 31 55 ,,	—	1	12	10 59 25 ,,	—	1	—
10 32 32 ,,	—	1	20	11 00 01 ,,	—	1	15
10 33 00 ,,	—	1	18	11 00 41 ,,	—	1	—
10 33 23 ,,	—	1	12	11 00 50 ,,	—	1	—
10 34 15 ,,	—	1	17	11 00 59 ,,	—	1	—
10 35 48 ,,	—	1	—	11 01 12 ,,	—	1	—
10 36 09 ,,	—	1	—	11 01 19 ,,	—	1	23
10 36 21 ,,	—	1	—	11 03 00 ,,	—	1	27
10 37 23 ,,	—	1	—	11 03 52 ,,	—	1	—
10 38 24 ,,	—	1	—	11 04 04 ,,	—	1	—
10 38 36 ,,	—	1	—	11 04 16 ,,	—	1	21
10 38 52 ,,	—	1	15	11 05 08 ,,	—	1	21
10 39 41 ,,	—	1	21	11 05 52 ,,	—	1	11
10 40 44 ,,	—	1	—	11 06 07 ,,	—	1	19
10 42 02 ,,	—	1	—	11 06 43 ,,	—	1	23
10 42 25 ,,	—	1	—	11 07 26 ,,	—	1	—
10 42 33 ,,	—	1	18	11 07 37 ,,	—	1	21
10 43 25 ,,	—	1	22	11 09 48 ,,	—	1	15
10 45 22 ,,	—	1	24	11 10 20 ,,	—	1	19
10 46 13 ,,	—	1	—	11 11 11 ,,	—	1	21
10 46 25 ,,	—	1	—	11 12 12 ,,	—	1	18
10 46 59 ,,	—	1	19	11 13 23 ,,	—	1	31
10 47 44 ,,	—	1	25	11 14 35 ,,	—	1	27
10 48 32 ,,	—	1	12	11 15 37 ,,	—	1	—
10 49 17 ,,	—	1	—	11 15 48 ,,	—	1	—
10 49 29 ,,	—	1	—	11 16 04 ,,	—	1	23
10 49 53 ,,	—	1	20	11 16 56 ,,	—	1	25
10 50 35 ,,	—	1	—	11 17 45 ,,	—	1	25
10 51 00 ,,	—	1	15	11 19 07 ,,	—	1	22
10 52 08 ,,	—	1	21	11 19 52 ,,	—	1	31
10 52 53 ,,	—	1	—	11 21 13 ,,	—	1	—
10 53 12 ,,	—	1	—	11 21 27 ,,	—	1	25
10 53 37 ,,	—	1	—	11 22 18 ,,	—	1	—
10 53 56 ,,	—	1	21	11 22 28 ,,	—	1	—
10 54 27 ,,	—	1	—	11 22 41 ,,	—	1	20
10 54 37 ,,	—	1	28	11 23 32 ,,	—	1	—
10 55 32 ,,	—	1	30	11 23 34 ,,	—	1	—
10 56 51 ,,	—	1	41	11 24 06 ,,	—	1	—
10 58 14 ,,	—	1	—	11 24 23 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 4	sec.	μ	sec.	**AUG. 4**	sec.	μ	sec.
11 24 38 p.m.	—	1	—	11 49 28 p.m.	—	1	31
11 25 05 „	—	1	—	11 50 19 „	—	1	—
11 25 37 „	—	1	—	11 51 08 „	—	1	35
11 26 10 „	—	1	—	11 53 20 „	—	1	25
11 26 24 „	—	1	—	11 54 03 „	—	1	—
11 26 47 „	—	1	—	11 54 22 „	—	1	27
11 27 09 „	—	1	—	11 55 03 „	—	1	—
11 27 35 „	—	1	—	11 55 21 „	—	1	22
11 28 03 „	—	1	—	11 56 02 „	—	1	—
11 28 34 „	—	1	—	11 56 29 „	—	1	—
11 29 04 „	—	1	—	11 57 00 „	—	1	24
11 29 35 „	—	1	—	11 57 42 „	—	1	20
11 30 04 „	—	1	—	11 58 21 „	—	1	30
11 30 17 „	—	1	32	11 59 50 „	—	1	25
				AUG. 5			
11 32 29 „	—	1	—	0 00 22 a.m.	—	1	22
11 32 48 „	—	1	—	0 00 48 „	—	1	—
11 33 07 „	—	1	—	0 01 32 „	—	1	—
11 33 36 „	—	1	25	0 01 44 „	—	1	29
11 34 08 „	—	1	19	0 03 03 „	—	1	41
11 34 38 „	—	1	—	0 04 57 „	—	1	30
11 35 19 „	—	1	28	0 05 52 „	—	1	29
11 36 08 „	—	1	41	0 06 45 „	—	1	—
11 36 54 „	—	1	—	0 07 13 „	—	1	20
11 37 16 „	—	1	—	0 10 07 „	—	1	—
11 37 37 „	—	1	—	0 10 40 „	—	1	29
11 38 00 „	—	1	11	0 11 22 „	—	1	—
11 38 23 „	—	1	—	0 11 44 „	—	1	—
11 39 34 „	—	1	32	0 12 15 „	—	1	23
11 40 13 „	—	1	24	0 13 06 „	—	1	—
11 41 04 „	—	1	18	0 13 32 „	—	1	15
11 41 27 „	—	1	29	0 14 13 „	—	1	—
11 41 57 „	—	1	28	0 14 44 „	—	1	—
11 42 59 „	—	1	22	0 15 10 „	—	1	19
11 46 40 „	—	1	—	0 15 38 „	—	1	—
11 46 51 „	—	1	31	0 15 54 „	—	1	21
11 47 29 „	—	1	—	0 24 02 „	—	1	15
11 48 03 „	—	1	—	0 27 26 „	—	1	—
11 48 15 „	—	1	—	0 27 50 „	—	1	20
11 48 41 „	—	1	—	0 29 01 „	—	1	—
11 49 04 „	—	1	—	0 29 29 „	—	1	25

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 5	sec.	μ	sec.	**AUG. 5**	sec.	μ	sec.
0 31 17 a.m.	—	1	31	1 42 50 a.m.	—	1	—
0 32 20 ,,	—	1	40	1 43 18 ,,	—	1	—
0 33 15 ,,	—	1	—	1 45 10 ,,	—	1	28
0 33 32 ,,	—	1	—	2 06 29 ,,	—	1	31
0 38 31 ,,	—	1	22	2 07 01 ,,	—	1	35
0 52 03 ,,	—	1	45	2 08 37 ,,	—	1	40
0 54 54 ,,	—	1	30	2 09 46 ,,	—	1	26
0 56 38 ,,	—	1	41	2 11 41 ,,	—	1	32
0 57 52 ,,	—	1	24	2 12 46 ,,	—	1	23
0 59 15 ,,	—	1	—	2 13 57 ,,	—	1	20
0 59 57 ,,	—	1	41	2 17 25 ,,	—	1	21
1 00 59 ,,	—	1	49	2 22 37 ,,	—	1	24
1 02 06 ,,	—	1	40	2 24 54 ,,	—	1	30
1 03 13 ,,	—	1	36	2 28 10 ,,	—	1	24
1 04 34 ,,	—	1	27	2 28 45 ,,	—	1	19
1 06 53 ,,	—	1	15	2 31 32 ,,	—	1	18
1 07 24 ,,	—	1	12	2 32 50 ,,	—	1	24
1 07 57 ,,	—	1	14	2 33 32 ,,	—	1	—
1 09 18 ,,	—	1	14	2 33 46 ,,	—	1	39
1 09 42 ,,	—	1	14	2 36 11 ,,	—	1	21
1 10 43 ,,	—	1	22	2 49 20 ,,	—	1	19
1 12 59 ,,	—	1	32	2 53 31 ,,	—	1	23
1 15 23 ,,	—	1	—	6 37 33 ,,	—	1	27
1 15 43 ,,	—	1	—	6 38 21 ,,	—	1	40
1 16 05 ,,	—	1	—	7 28 12 ,,	—	1	16
1 16 37 ,,	—	1	20	7 29 44 ,,	—	1	20
1 17 43 ,,	—	1	26	7 49 43 ,,	—	1	31
1 19 43 ,,	—	1	31	7 57 20 ,,	—	1	28
1 20 25 ,,	—	1	23	7 58 04 ,,	—	1	40
1 21 11 ,,	—	1	—	7 59 08 ,,	—	1	—
1 21 44 ,,	—	1	—	7 59 40 ,,	—	1	32
1 22 12 ,,	—	1	—	8 00 35 ,,	—	1	44
1 22 35 ,,	—	1	—	8 22 48 ,,	—	1	33
1 22 51 ,,	—	1	—	8 24 39 ,,	—	1	46
1 23 09 ,,	—	1	26	9 03 12 ,,	—	1	33
1 24 12 ,,	—	1	31	10 04 10 ,,	—	1	50
1 25 10 ,,	—	1	—	10 29 14 ,,	—	1	35
1 35 24 ,,	—	1	22	10 30 44 ,,	—	1	44
1 38 19 ,,	—	1	21	10 34 44 ,,	—	1	—
1 40 42 ,,	—	1	31	10 35 02 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 5	sec.	μ	sec.	**AUG. 5**	sec.	μ	sec.
10 36 08 a.m.	—	1	—	10 55 34 p.m.	—	1	—
10 36 38 ,,	—	1	—	10 56 29 ,,	—	1	—
10 48 17 ,,	—	1	32	10 57 04 ,,	—	1	—
10 49 02 ,,	—	1	—	10 57 36 ,,	—	1	26
10 49 40 ,,	—	1	—	10 58 54 ,,	—	1	43
10 55 43 ,,	—	1	—	11 06 10 ,,	4.0	1	24
10 56 29 ,,	—	1	—	11 06 41 ,,	—	1	38
10 57 01 ,,	—	1	20	11 07 39 ,,	—	1	—
11 07 05 ,,	—	1	28	11 08 15 ,,	—	1	—
0 37 47 p.m.	—	1	38	11 08 42 ,,	—	1	—
2 53 51 ,,	—	1	17	11 09 40 ,,	—	1	—
2 54 24 ,,	—	1	—	11 10 04 ,,	—	1	—
2 54 53 ,,	—	1	24	11 10 30 ,,	—	1	—
2 56 21 ,,	—	1	18	11 10 46 ,,	—	1	—
3 00 46 ,,	—	1	—	11 11 02 ,,	—	1	—
3 01 05 ,,	—	1	39	11 11 13 ,,	—	1	—
3 11 32 ,,	—	1	26	11 12 16 ,,	—	1	—
3 12 22 ,,	—	1	27	11 12 44 ,,	—	1	—
3 12 58 ,,	—	1	31	11 12 59 ,,	—	1	—
3 13 48 ,,	—	1	34	11 13 32 ,,	—	1	—
3 15 46 ,,	—	1	26	11 13 54 ,,	—	1	—
3 18 16 ,,	—	1	17	11 14 36 ,,	—	1	—
4 02 20 ,,	—	1	23	11 15 34 ,,	—	1	—
4 09 14 ,,	—	1	28	11 16 10 ,,	—	1	—
5 00 27 ,,	—	1	14	11 16 38 ,,	—	1	—
5 03 40 ,,	—	1	28	11 16 59 ,,	—	1	28
5 04 17 ,,	—	1	—	11 17 38 ,,	—	1	—
5 04 44 ,,	—	1	42	11 18 28 ,,	—	1	—
5 05 49 ,,	—	1	28	11 18 59 ,,	—	1	—
10 36 53 ,,	4.0	1	36	11 19 32 ,,	—	1	—
10 48 29 ,,	—	1	—	11 20 02 ,,	—	1	—
10 49 06 ,,	—	1	20	11 21 09 ,,	—	1	—
10 50 36 ,,	—	1	—	11 21 44 ,,	—	1	—
10 51 05 ,,	—	1	—	11 22 03 ,,	—	1	—
10 51 50 ,,	—	1	—	11 22 32 ,,	—	1	—
10 52 12 ,,	—	1	—	11 23 04 ,,	—	1	—
10 52 55 ,,	—	1	—	11 23 24 ,,	—	1	—
10 53 17 ,,	—	1	—	11 23 59 ,,	—	1	—
10 54 07 ,,	—	1	32	11 25 15 ,,	—	1	—
10 55 00 ,,	—	1	—	11 25 44 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 5	sec.	μ	sec.
11 26 03 p.m.	—	1	—
11 26 29 „	—	1	—
11 27 09 „	—	1	—
11 27 41 „	—	1	—
11 28 11 „	—	1	—
11 28 38 „	—	1	—
11 29 13 „	—	1	—
11 29 38 „	—	1	—
11 29 51 „	—	1	—
11 30 14 „	—	1	—
11 30 35 „	—	1	—
11 31 17 „	—	1	—
11 31 48 „	—	1	—
11 32 19 „	—	1	—
11 32 48 „	—	1	—
11 33 19 „	—	1	—
11 33 39 „	—	1	—
11 33 54 „	—	1	—
11 34 25 „	—	1	—
11 34 50 „	—	1	—
11 35 38 „	—	1	—
11 36 24 „	—	1	—
11 36 55 „	—	1	—
11 38 18 „	—	1	—
11 38 51 „	—	1	—
11 39 29 „	—	1	—
11 39 47 „	—	1	—
11 40 20 „	—	1	—
11 40 46 „	—	1	—
11 41 09 „	—	1	—
11 41 53 „	—	1	—
11 42 16 „	—	1	—
11 43 03 „	—	1	—
11 43 27 „	—	1	—
11 44 01 „	—	1	—
11 44 27 „	—	1	—
11 45 04 „	—	1	—
11 45 48 „	—	1	—
11 46 20 „	—	1	—
11 47 00 „	—	1	—
AUG. 5	sec.	μ	sec.
11 47 20 p.m.	—	1	—
11 47 48 „	—	1	—
11 48 33 „	—	1	—
11 49 28 „	—	1	—
11 50 02 „	—	1	—
11 50 50 „	—	1	—
11 51 24 „	—	1	—
11 51 47 „	—	1	—
11 52 33 „	—	1	—
11 53 08 „	—	1	—
11 54 06 „	—	1	—
11 54 46 „	—	1	—
11 55 19 „	—	1	—
11 56 09 „	—	1	—
11 56 29 „	—	1	—
11 56 46 „	—	1	—
11 57 17 „	—	1	32
11 58 07 „	—	1	—
11 58 36 „	—	1	28
11 59 12 „	—	1	—
11 59 47 „	—	1	37
AUG. 6			
0 00 35 a.m.	—	1	—
0 01 08 „	—	1	—
0 01 48 „	—	1	35
0 02 57 „	—	1	—
0 03 54 „	—	1	—
0 04 22 „	—	1	—
0 05 18 „	—	1	—
0 05 57 „	—	1	—
0 06 38 „	—	1	20
0 08 05 „	—	1	—
0 08 57 „	—	1	—
0 09 37 „	—	1	—
0 10 37 „	—	1	—
0 11 27 „	—	1	—
0 11 59 „	—	1	—
0 12 49 „	—	1	—
0 13 04 „	—	1	—
0 13 48 „	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 6	sec.	μ	sec.	**AUG. 6**	sec.	μ	sec.
0 14 40 a.m.	—	1	—	0 44 10 a.m.	—	1	—
0 15 49 ,,	—	1	—	0 44 52 ,,	—	1	—
0 16 26 ,,	—	1	—	0 45 20 ,,	—	1	—
0 18 27 ,,	—	1	—	0 45 56 ,,	—	1	—
0 18 55 ,,	—	1	—	0 46 31 ,,	—	1	—
0 19 25 ,,	—	1	—	0 47 11 ,,	—	1	—
0 19 49 ,,	—	1	—	0 47 28 ,,	—	1	—
0 20 07 ,,	—	1	—	0 48 24 ,,	—	1	51
0 20 24 ,,	—	1	—	0 49 36 ,,	—	1	—
0 21 00 ,,	—	1	—	0 49 56 ,,	—	1	—
0 22 09 ,,	—	1	—	0 50 18 ,,	—	1	—
0 23 16 ,,	—	1	—	0 50 41 ,,	—	1	—
0 23 53 ,,	—	1	—	0 52 02 ,,	—	1	—
0 24 44 ,,	—	1	23	0 52 35 ,,	—	1	—
0 25 28 ,,	—	1	—	0 53 29 ,,	—	1	—
0 27 01 ,,	—	1	—	0 54 18 ,,	—	1	—
0 27 27 ,,	—	1	—	0 54 52 ,,	—	1	—
0 27 53 ,,	—	1	—	0 55 10 ,,	—	1	—
0 28 19 ,,	—	1	—	0 55 50 ,,	—	1	—
0 28 40 ,,	—	1	—	0 56 14 ,,	—	1	—
0 29 31 ,,	—	1	—	0 57 00 ,,	—	1	—
0 30 00 ,,	—	1	—	0 58 00 ,,	—	1	—
0 30 40 ,,	—	1	—	0 58 42 ,,	—	1	—
0 31 06 ,,	—	1	—	0 59 26 ,,	—	1	—
0 31 55 ,,	—	1	—	1 00 21 ,,	—	1	—
0 33 28 ,,	—	1	—	1 00 47 ,,	—	1	—
0 34 50 ,,	—	1	—	1 01 48 ,,	—	1	—
0 36 04 ,,	—	1	—	1 02 23 ,,	—	1	—
0 36 57 ,,	—	1	—	1 03 00 ,,	—	1	—
0 37 18 ,,	—	1	—	1 04 24 ,,	—	1	—
0 38 40 ,,	—	1	—	1 05 38 ,,	—	1	—
0 38 56 ,,	—	1	—	1 06 34 ,,	—	1	—
0 39 14 ,,	—	1	—	1 07 32 ,,	—	1	—
0 40 06 ,,	—	1	—	1 08 30 ,,	—	1	—
0 40 39 ,,	—	1	—	1 08 58 ,,	—	1	—
0 41 12 ,,	—	1	—	1 10 51 ,,	—	1	—
0 41 37 ,,	—	1	—	1 11 36 ,,	—	1	—
0 42 24 ,,	—	1	—	1 12 17 ,,	—	1	11
0 42 51 ,,	—	1	—	1 14 48 ,,	—	1	23
0 43 34 ,,	—	1	—	1 17 06 ,,	—	1	17

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 6	sec.	μ	sec.
1 19 15 a.m.	—	1	31
1 22 13 ,,	—	1	—
1 24 00 ,,	—	1	—
1 24 27 ,,	—	1	—
1 24 59 ,,	—	1	51
1 27 43 ,,	—	1	—
1 30 08 ,,	—	1	—
1 30 33 ,,	—	1	—
1 30 56 ,,	—	1	—
1 31 42 ,,	—	1	—
1 32 38 ,,	—	1	—
1 33 55 ,,	—	1	—
1 34 37 ,,	—	1	—
1 36 32 ,,	—	1	—
1 38 26 ,,	—	1	—
1 39 20 ,,	—	1	—
1 40 14 ,,	—	1	—
1 40 54 ,,	—	1	—
1 41 46 ,,	—	1	—
1 42 48 ,,	—	1	30
1 44 43 ,,	—	1	—
1 45 17 ,,	—	1	—
1 46 02 ,,	—	1	—
1 46 36 ,,	—	1	20
1 47 18 ,,	—	1	15
1 47 45 ,,	—	1	—
1 48 10 ,,	—	1	—
1 48 43 ,,	—	1	31
1 49 35 ,,	—	1	—
1 49 54 ,,	—	1	32
1 50 36 ,,	—	1	—
1 51 26 ,,	—	1	—
1 52 39 ,,	—	1	—
1 53 46 ,,	—	1	—
1 54 38 ,,	—	1	—
1 55 33 ,,	—	1	—
1 56 09 ,,	—	1	—
1 56 38 ,,	—	1	—
1 57 20 ,,	—	1	—
1 58 18 ,,	—	1	—
AUG. 6	sec.	μ	sec.
1 58 46 a.m.	—	1	—
1 59 10 ,,	—	1	—
1 59 45 ,,	—	1	—
2 00 08 ,,	—	1	—
2 00 45 ,,	—	1	—
2 01 45 ,,	—	1	—
2 02 30 ,,	—	1	—
2 03 10 ,,	—	1	—
2 04 24 ,,	—	1	—
2 05 09 ,,	—	1	—
2 05 31 ,,	—	1	—
2 06 11 ,,	—	1	—
2 06 53 ,,	—	1	—
2 07 29 ,,	—	1	—
2 08 02 ,,	—	1	—
2 09 02 ,,	—	1	—
2 09 35 ,,	—	1	—
2 09 57 ,,	—	1	—
2 10 45 ,,	—	1	—
2 11 17 ,,	—	1	—
2 11 56 ,,	—	1	—
2 12 38 ,,	—	1	—
2 13 01 ,,	—	1	—
2 13 24 ,,	—	1	—
2 14 10 ,,	—	1	—
2 15 10 ,,	—	1	—
2 15 31 ,,	—	1	—
2 16 18 ,,	—	1	—
2 17 01 ,,	—	1	—
2 17 40 ,,	—	1	—
2 18 13 ,,	—	1	—
2 18 43 ,,	—	1	—
2 19 14 ,,	—	1	—
2 19 39 ,,	—	1	30
2 20 21 ,,	—	1	—
2 21 24 ,,	—	1	—
2 21 58 ,,	—	1	—
2 22 14 ,,	—	1	—
2 23 09 ,,	—	1	—
2 23 40 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 6	sec.	μ	sec.	AUG. 6	sec.	μ	sec.
2 24 04 a.m.	—	1	—	2 52 09 a.m.	—	1	—
2 24 49 „	—	1	—	2 52 39 „	—	1	—
2 25 09 „	—	1	—	2 54 02 „	—	1	—
2 25 30 „	—	1	—	2 54 47 „	—	1	—
2 25 47 „	—	1	—	2 55 46 „	—	1	—
2 26 10 „	—	1	—	2 56 17 „	—	1	—
2 26 33 „	—	1	—	2 56 57 „	—	1	—
2 27 03 „	—	1	—	2 58 00 „	—	1	—
2 27 27 „	—	1	—	2 58 36 „	—	1	—
2 27 57 „	—	1	—	2 59 11 „	—	1	—
2 28 24 „	—	1	—	3 00 28 „	—	1	—
2 29 02 „	—	1	—	3 00 57 „	—	1	—
2 29 39 „	—	1	—	3 02 23 „	—	1	—
2 30 43 „	—	1	—	3 03 09 „	—	1	—
2 31 12 „	—	1	—	3 05 17 „	—	1	—
2 31 41 „	—	1	—	3 06 38 „	—	1	36
2 33 22 „	—	1	—	3 08 10 „	—	1	43
2 33 52 „	—	1	—	3 09 29 „	—	1	22
2 34 11 „	—	1	—	3 10 29 „	—	1	31
2 35 01 „	—	1	—	3 13 07 „	—	1	—
2 35 39 „	—	1	—	3 13 52 „	—	1	25
2 36 04 „	—	1	—	3 14 29 „	—	1	—
2 36 56 „	—	1	—	3 15 29 „	—	1	47
2 37 25 „	—	1	—	3 20 15 „	—	1	—
2 37 57 „	—	1	—	3 20 57 „	—	1	40
2 38 31 „	—	1	—	3 23 25 „	—	1	43
2 39 07 „	—	1	—	3 24 28 „	—	1	32
2 39 47 „	—	1	—	3 28 10 „	—	1	—
2 41 00 „	—	1	—	3 30 27 „	—	1	29
2 41 29 „	—	1	—	3 31 20 „	—	1	—
2 42 11 „	—	1	—	3 36 58 „	—	1	30
2 42 51 „	—	1	—	3 38 31 „	—	1	—
2 43 23 „	—	1	—	3 48 53 „	—	1	—
2 44 18 „	—	1	—	3 51 03 „	—	1	18
2 45 08 „	—	1	—	3 53 34 „	—	1	—
2 46 40 „	—	1	—	4 25 59 „	—	1	42
2 47 35 „	—	1	—	4 33 07 „	—	1	—
2 49 12 „	—	1	—	5 26 03 „	—	1	28
2 50 17 „	—	1	—	5 26 46 „	—	1	—
2 50 49 „	—	1	—	5 27 37 „	—	1	32

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 6	sec.	μ	sec.
10 40 52 a.m.	2.0	1	17
9 19 16 p.m.	0.4	2	14
AUG. 7			
7 43 21 a.m.	2.1	2	—
7 43 36 ,,	—	1	26
2 44 57 p.m.	5.0	3	—
2 45 28 ,,	—	1	26
10 01 46 ,,	—	1	24
AUG. 8			
3 37 21 a.m.	2.0	2	16
5 28 21 ,,	—	1	49
6 28 26 ,,	2.0	2	50
8 02 31 ,,	3.5	2	—
8 02 55 ,,	—	1	—
8 03 09 ,,	—	1	—
8 03 32 ,,	—	2	—
8 03 50 ,,	—	2	30
8 31 29 ,,	—	2	51
4 19 22 p.m.	—	1	—
4 19 36 ,,	—	1	24
6 34 45 ,,	—	2	—
6 35 25 ,,	—	1	—
6 48 23 ,,	—	1	—
6 48 37 ,,	—	1	—
6 48 48 ,,	—	1	—
6 49 05 ,,	—	1	—
6 49 32 ,,	—	1	—
6 49 44 ,,	—	1	—
6 49 59 ,,	—	1	—
6 50 14 ,,	—	1	—
6 50 30 ,,	—	1	—
6 51 13 ,,	—	1	—
6 51 28 ,,	—	1	—
6 51 55 ,,	—	1	—
6 58 50 ,,	1.5	2	45

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 8	sec.	μ	sec.
7 14 08 p.m.	—	1	—
7 14 35 ,,	—	1	—
7 15 02 ,,	—	1	—
7 15 25 ,,	—	1	—
7 15 35 ,,	—	1	—
8 23 38 ,,	1.8	2	44
AUG. 9			
8 05 23 a.m.	—	1	26
9 30 11 ,,	—	1	48
AUG. 10			
1 41 04 a.m.	4.0	2	41
1 17 51 p.m.	—	2	29
1 20 52 ,,	—	2	—
1 21 04 ,,	—	1	—
1 21 15 ,,	—	1	—
1 21 36 ,, (1)	—	1	—
1 22 04 ,,	—	1	—
1 22 22 ,, (2)	—	1	39
1 23 14 ,,	—	1	25
1 23 45 ,,	—	1	25
1 25 20 ,,	—	1	39
1 29 34 ,,	—	1	—
1 29 48 ,,	—	2	—
1 30 00 ,,	—	2	—
1 30 17 ,, (3)	—	1	—
1 30 53 ,, (4)	—	1	—
1 31 29 ,,	—	1	18
AUG. 11			
5 54 51 a.m.	4.0	1	—
5 55 14 ,,	—	1	49
5 57 04 ,,	—	1	—
5 57 12 ,,	—	1	16
0 30 58 p.m.	1.7	3	41
0 32 48 ,,	—	1	29
0 34 59 ,, (5)	—	1	29
0 35 57 ,,	—	1	—

(1), (2), (3), (4), and (5). The disturbances were each composed of a series of small vibrations which were remarkably regular.

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 11	sec.	μ	sec.	**AUG. 12**	sec.	μ	sec.
0 36 25 p.m.	—	1	—	1 15 43 p.m.	2.3	3	—
0 37 01 ,,	—	1	—	1 16 12 ,,	—	1	26
0 37 21 ,,	—	1	—	1 17 57 ,, (5)	—	1	24
0 38 03 ,,	—	1	—	1 18 26 ,,	—	1	38
0 38 28 ,,	—	1	—	1 19 30 ,,	—	1	34
0 40 08 ,,	—	1	—	1 20 15 ,,	—	1	17
0 40 44 ,,	—	1	20	1 21 41 ,,	—	1	20
0 41 29 ,,	—	1	23	1 22 08 ,,	—	1	23
0 42 20 ,,	—	1	—	1 23 25 ,,	—	1	30
0 43 17 ,,	—	1	—	1 24 07 ,,	—	1	—
6 15 04 ,,	2.9	9	—	1 24 28 ,,	—	1	18
6 15 30 ,,	—	1	—	1 24 50 ,,	—	1	17
7 19 04 ,,	4.3	2	33	1 25 10 ,,	—	1	26
8 03 54 ,,	—	2	39	1 25 56 ,, (6)	—	1	16
10 06 46 ,,	2.4	2	14	1 26 40 ,, (7)		4	
10 20 59 ,,	—	2	32	1 26 57 ,,			
AUG. 12				1 27 12 ,,			
0 07 31 a.m.	—	2	22	1 31 33 ,, (8)			
4 59 52 ,,	—	1	—	1 31 36 ,, (9)	—	1	30
5 00 21 ,,	—	1	25	1 32 10 ,, (10)		2	
5 20 31 ,,	1.2	3	—	1 38 12 ,, (11)			
5 21 18 ,,	—	1	—	1 38 18 ,,	—	1	35
5 21 42 ,,	—	1	24	1 39 01 ,, (12)	—	1	56
5 25 54 ,,	—	1	—	1 41 26 ,,	—	1	27
5 26 17 ,,	—	1	30	1 42 55 ,,	—	1	50
5 33 12 ,,	—	1	25	1 44 03 ,,	—	1	27
5 47 46 ,, (1)	—	1	—	1 44 40 ,,	—	1	39
5 48 19 ,, (2)	—	1	—	1 46 49 ,,	—	1	17
5 49 19 ,, (3)	—	1	—	1 47 43 ,, (13)	—	1	48
5 49 44 ,,	—	1	—	1 48 38 ,, (14)	—	1	—
5 49 51 ,, (4)	—	1	42	1 49 19 ,,	—	1	22
11 15 13 ,,	3.7	2	22	1 50 00 ,, (15)	—	1	37
11 41 49 ,,	2.4	2	24	1 55 43 ,,	—	1	—
11 42 26 ,,	—	1	—	1 55 58 ,, (16)	—	1	39
0 04 59 p.m.	—	1	18	1 57 10 ,,	—	1	—

(1),....(4); (5) to (6); (9); and (12),....(16): the disturbances were each composed of a series of regular vibrations.

(7) to (8) and also (10) to (11): the motion was continuous and regular.

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 12	sec.	μ	sec.	**AUG. 12**	sec.	μ	sec.
1 57 42 p.m.	—	1	30	11 33 04 p.m.	—	3	—
1 59 35 ,, (1)	—	1	85	11 33 31 ,,	—	1	—
4 01 23 ,,	—	3	12	11 33 42 ,,	—	4	—
7 44 02 ,,	—	1	7	11 34 02 ,,	—	1	—
7 44 29 ,,	—	1	—	11 34 12 ,,	—	2	—
7 44 38 ,,	1.2	2	—	11 34 44 ,,	—	3	—
7 45 01 ,,	—	2	—	11 35 02 ,,	—	2	—
7 45 08 ,, (2)	—	85	120	11 35 17 ,,	—	2	—
11 18 35 ,,	—	1	17	11 35 36 ,,	—	4	—
11 20 03 ,,	—	1	16	11 36 09 ,,	—	4	—
11 20 33 ,, (3)	0.42	473	260	11 36 40 ,,	—	6	—
11 23 21 ,,	—	1	—	11 37 00 ,,	—	7	—
11 24 00 ,,	—	2	—	11 37 09 ,,	—	4	—
11 24 38 ,,	—	2	—	11 37 24 ,,	—	3	—
11 25 06 ,,	—	2	—	11 37 44 ,,	—	3	—
11 25 52 ,,	—	4	—	11 37 53 ,,	—	4	—
11 26 17 ,,	—	2	—	11 38 19 ,,	—	4	—
11 26 25 ,,	—	2	—	11 38 43 ,,	—	3	—
11 26 56 ,,	—	2	—	11 38 52 ,,	—	3	—
11 27 29 ,,	—	1	—	11 39 13 ,,	—	2	—
11 27 43 ,,	—	1	—	11 39 39 ,,	—	2	—
11 28 13 ,,	—	1	—	11 39 51 ,,	—	4	—
11 28 26 ,,	—	1	—	11 40 03 ,,	—	3	—
11 28 36 ,,	—	1	—	11 40 18 ,,	—	4	—
11 28 54 ,,	—	1	—	11 40 38 ,,	—	1	—
11 29 15 ,,	—	1	—	11 41 02 ,,	—	1	—
11 30 41 ,,	—	1	—	11 41 12 ,,	—	1	—
11 30 49 ,,	—	1	—	11 41 22 ,,	—	1	—
11 30 59 ,,	—	1	—	11 41 37 ,,	—	1	—
11 31 26 ,,	—	1	—	11 41 51 ,,	—	1	—
11 31 40 ,,	—	2	—	11 42 05 ,,	—	1	—
11 31 51 ,,	—	2	—	11 42 24 ,,	—	1	—
11 32 00 ,,	—	4	—	11 42 54 ,,	—	1	—
11 32 25 ,,	—	2	—	11 43 28 ,,	—	1	—
11 32 40 ,,	—	3	—	11 43 45 ,,	—	1	—

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(1) Between 1.55.58 and 1.59.35 p.m., the disturbances were each composed of regular vibrations.

(2) Strong explosion.

(3) Very strong explosion, followed by powerful smoke emissions.

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 12	sec.	μ	sec.	AUG. 13	sec.	μ	sec.
11 44 03 p.m.	—	1	—	9 15 36 a.m.	—	1	—
11 44 25 „	—	1	—	9 15 48 „	—	1	—
11 44 47 „	—	1	—	9 16 01 „	—	1	—
11 45 01 „	—	1	—	9 16 16 „	—	1	—
11 45 20 „	—	1	—	9 16 29 „	—	1	—
11 45 29 „	—	1	—	9 16 47 „	—	1	—
11 45 41 „	—	1	—	9 16 56 „	—	1	—
11 46 07 „	—	1	—	9 17 04 „	—	1	—
11 46 21 „	—	1	—	9 17 17 „	—	1	—
11 46 35 „	—	1	—	9 17 31 „	—	1	—
11 46 47 „	—	1	—	9 17 50 „	—	1	—
11 47 00 „	—	1	—	9 18 04 „	—	1	—
11 47 13 „	—	1	—	9 18 12 „	—	1	—
11 47 25 „	—	1	—	9 18 28 „	—	1	—
11 47 36 „	—	1	—	9 18 42 „	—	1	—
11 47 46 „	—	1	—	9 18 56 „	—	1	—
11 48 08 „	—	1	—	9 19 08 „	—	1	—
11 48 40 „	—	1	—	9 19 22 „	—	1	—
11 49 10 „	—	1	—	9 19 39 „	—	1	—
11 49 41 „	—	1	—	9 19 49 „	—	1	—
11 49 52 „	—	1	—	9 20 08 „	—	1	—
11 50 21 „	—	1	—	9 20 20 „	—	1	—
11 50 40 „	—	1	—	9 20 37 „	—	1	—
11 51 02 „	—	1	—	9 20 47 „	—	1	—
11 51 39 „	—	1	—	9 21 06 „	—	1	—
11 51 56 „	—	1	—	9 21 38 „	—	1	—
11 52 17 „	—	1	—	9 21 44 „	—	1	—
11 52 40 „	—	1	—	9 21 55 „	—	2	—
11 52 57 „	—	1	—	9 22 07 „	—	1	—
11 53 11 „	—	1	—	9 22 16 „	—	1	—
11 53 48 „	—	1	—	9 22 28 „	—	1	—
11 54 17 „	—	1	—	9 22 40 „	—	1	—
11 57 43 „	—	1	—	9 23 00 „	—	1	—
11 57 52 „	—	1	—	9 23 12 „	—	1	—
11 58 21 „	—	1	—	9 23 35 „	—	1	—
AUG. 13							
9 14 13 a.m.	—	1	22	9 23 49 „	—	1	—
9 14 41 „	—	1	—	9 24 01 „	—	1	—
9 14 56 „	—	1	—	9 24 20 „	—	1	—
9 15 09 „	—	1	—	9 24 41 „	—	1	—
9 15 19 „	—	1	—	9 24 58 „	—	1	10

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 13	sec.	μ	sec.	**AUG. 13**	sec.	μ	sec.
9 25 28 a.m.	—	1	—	5 45 59 p.m.	—	2	—
9 26 07 ,,	—	1	11	5 46 14 ,,	—	2	—
9 26 35 ,,	—	1	—	5 46 23 ,,	—	2	—
9 26 51 ,,	—	1	20	5 46 33 ,,	—	2	—
0 13 22 p.m.	—	2	28	5 46 47 ,,	—	2	—
0 32 16 ,,	—	1	—	5 46 58 ,,	—	2	—
0 32 33 ,,	—	1	—	5 47 07 ,,	—	2	—
0 32 46 ,,	—	1	—	5 47 17 ,,	—	2	—
0 33 02 ,,	—	1	—	5 47 27 ,,	—	1	—
0 33 28 ,,	—	1	—	5 47 47 ,,	—	1	—
0 50 18 ,,	—	1	28	5 47 59 ,,	—	1	—
0 50 55 ,,	—	1	26	5 48 09 ,,	—	1	—
1 34 54 ,,	—	2	—	5 48 18 ,,	—	1	—
1 35 20 ,,	—	2	—	5 48 27 ,,	—	1	—
1 35 54 ,,	—	2	—	5 48 43 ,,	—	1	—
1 36 08 ,,	—	2	—	5 48 59 ,,	—	1	—
1 36 33 ,,	—	2	—	5 49 13 ,,	—	1	—
1 36 52 ,,	—	1	—	5 49 24 ,,	—	1	—
1 37 13 ,,	—	1	—	5 49 38 ,,	—	1	—
1 37 51 ,,	—	1	—	5 49 54 ,,	—	1	—
5 41 23 ,,	1.5	3	—	5 50 14 ,,	—	1	—
5 41 40 ,, (1)	3.2	23	—	5 50 23 ,,	—	1	—
5 42 00 ,,	—	4	—	5 50 37 ,,	—	1	—
5 42 06 ,,	—	2	—	5 51 06 ,,	—	1	23
5 42 13 ,,	—	2	—	5 51 42 ,,	—	1	—
5 42 23 ,,	—	2	—	5 51 53 ,,	—	1	12
5 42 37 ,,	—	2	—	5 54 53 ,,	—	1	12
5 42 49 ,,	—	2	—	5 55 15 ,,	—	1	12
5 43 03 ,,	—	1	—	5 55 30 ,,	—	1	16
5 43 18 ,,	—	1	—	6 02 18 ,,	—	1	27
5 43 30 ,,	—	1	—	6 03 38 ,,	—	1	—
5 43 43 ,,	—	2	—	6 04 05 ,,	—	1	—
5 43 57 ,,	—	1	—	6 04 24 ,,	—	2	—
5 44 11 ,,	—	2	—	6 04 47 ,,	—	1	—
5 44 19 ,,	—	1	—	6 04 59 ,,	—	2	—
5 44 29 ,,	—	1	—	6 05 23 ,,	—	2	—
5 44 44 ,,	—	2	—	6 05 43 ,,	—	2	—
5 44 59 ,,	—	2	—	6 06 00 ,,	—	2	—
5 45 31 ,,	—	2	—	6 06 20 ,,	—	2	—
5 45 43 ,,	—	3	—	6 06 34 ,,	—	2	—

(1) Strong explosion.

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 13	sec.	μ	sec.	**AUG. 13**	sec.	μ	sec.
6 06 45 p.m.	—	1	—	6 39 45 p.m.	—	1	—
6 06 50 „	—	1	—	6 40 02 „	—	1	—
6 07 12 „	—	1	—	6 40 13 „	—	1	—
6 07 24 „	—	2	—	6 40 23 „	—	1	—
6 07 40 „	—	3	—	6 40 38 „	—	1	—
6 07 57 „	—	2	—	6 40 52 „	—	1	—
6 08 12 „	—	2	—	6 41 01 „	—	1	—
6 08 22 „	—	4	—	6 41 11 „	—	1	—
6 08 42 „	—	3	—	6 41 26 „	—	1	—
6 08 56 „	—	2	—	6 41 43 „	—	1	—
6 09 13 „	—	2	—	6 42 02 „	—	1	—
6 09 30 „	—	2	—	6 42 18 „	—	1	—
6 09 45 „	—	1	—	6 42 35 „	—	1	—
6 10 11 „	—	2	—	6 42 47 „	—	1	—
6 10 28 „	—	3	—	6 43 02 „	—	1	—
6 10 55 „	—	2	—	6 43 21 „	—	1	—
6 11 15 „	—	2	—	6 43 40 „	—	1	—
6 11 33 „	—	2	—	6 43 57 „	—	1	—
6 12 00 „	—	2	—	6 44 30 „	—	1	—
6 12 20 „	—	1	—	6 44 45 „	—	1	—
6 12 32 „	—	1	—	6 48 25 „	—	1	—
6 12 45 „	—	1	—	6 48 51 „	—	1	—
6 13 08 „	—	1	—	6 49 08 „	—	1	—
6 13 26 „	—	1	—	6 49 26 „	—	1	28
6 13 46 „	—	1	—	6 52 47 „	—	1	—
6 13 59 „	—	1	—	6 52 57 „	—	1	—
6 14 08 „	—	1	—	6 53 13 „	—	1	—
6 14 22 „	—	1	—	7 27 16 „	—	1	19
6 14 42 „	—	1	—	9 56 26 „	—	1	—
6 15 02 „	—	1	—	9 56 39 „	—	1	—
6 15 27 „	—	1	—	9 56 53 „	—	1	—
6 15 45 „	—	1	—	9 57 10 „	—	1	—
6 16 07 „	—	1	—	9 57 58 „	—	2	27
6 16 22 „	—	1	—	10 37 56 „	0.6	1	16
6 16 33 „	—	1	—	10 43 05 „	—	1	—
6 16 47 „	—	1	—	10 43 20 „	—	1	—
6 17 01 „	—	1	—	10 43 34 „	—	1	—
6 17 14 „	—	1	—	10 43 53 „	—	1	—
6 33 50 „	—	1	24	10 44 00 „	—	1	26
6 39 27 „	—	1	14	11 07 15 „	1.1	4	39

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 13	sec.	μ	sec.	**AUG. 14**	sec.	μ	sec.
11 51 17 p.m.	1.1	2	27	6 09 19 a.m.	—	1	12
11 54 01 ,,	—	1	—	6 13 00 ,,	—	1	13
11 54 19 ,,	—	1	—	6 15 24 ,,	—	1	15
11 54 42 ,,	—	1	—	6 21 17 ,,	—	2	31
11 55 01 ,,	—	1	—	6 23 45 ,,	1.6	1	18
11 55 11 ,,	—	1	—	6 25 44 ,,	—	1	10
11 55 29 ,,	—	1	—	6 26 54 ,,	—	1	16
11 55 53 ,,	—	1	—	6 29 15 ,,	1.9	2	24
11 56 08 ,,	—	1	—	6 30 58 ,,	—	1	25
11 56 26 ,,	—	1	—	6 52 52 ,,	—	1	21
11 56 48 ,,	—	1	—	6 59 01 ,,	—	1	—
11 57 22 ,,	0.8	1	20	6 59 15 ,,	—	1	—
AUG. 14				7 15 08 ,,	—	3	38
0 28 03 a.m.	9.7	1	13	7 21 33 ,, (1)	—	2	35
0 39 02 ,,	1.2	3	39	7 22 13 ,,	—	1	—
2 59 38 ,,	—	1	—	7 22 30 ,,	—	1	—
2 59 45 ,,	1.3	6	51	7 22 45 ,,	—	2	—
3 04 55 ,,	1.6	2	20	7 23 05 ,,	—	1	—
3 10 46 ,,	1.4	2	15	7 23 22 ,,	—	1	—
3 20 36 ,,	—	1	11	7 23 47 ,,	—	1	—
3 21 36 ,,	—	1	19	7 24 10 ,,	—	1	—
3 34 08 ,,	—	1	13	7 24 32 ,,	—	1	—
3 38 05 ,,	—	2	20	7 25 11 ,, (2)	—	1	23
4 14 56 ,,	1.6	2	—	7 28 24 ,,	—	2	—
4 15 13 ,,	—	1	22	7 28 38 ,,	—	1	28
4 29 00 ,,	9.5	2	18	7 33 32 ,, (3)	—	1	—
4 32 02 ,,	—	1	15	7 34 02 ,,	—	2	—
4 44 35 ,,	1.4	2	30	7 34 23 ,,	—	2	—
5 05 54 ,,	—	1	22	7 34 49 ,,	—	2	—
5 31 26 ,,	9.4	2	31	7 35 03 ,,	—	1	—
5 34 23 ,,	—	1	23	7 35 15 ,,	—	1	—
5 35 51 ,,	—	1	11	7 35 40 ,,	—	1	—
5 46 49 ,,	—	2	—	7 35 56 ,,	—	1	—
5 47 10 ,,	—	3	37	7 36 13 ,,	—	1	—
6 05 25 ,,	—	1	21	7 36 32 ,,	—	1	—

(1) to (2): the disturbances were almost continuous.

(3): between 7.33.32 and 7.51.11 a.m., the disturbances were continuous.

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 14	sec.	μ	sec.	AUG. 14	sec.	μ	sec.
7 36 45 a.m.	—	1	—	7 51 11 a.m.	—	1	20
7 37 12 „	—	1	—	8 53 28 „	1.5	2	17
7 37 35 „	—	1	—	9 11 05 „	1.2	2	13
7 37 47 „	—	1	—	9 30 59 „	—	2	27
7 38 07 „	—	1	—	9 40 50 „	—	1	9
7 38 31 „	—	1	—	11 01 06 „	0.3	8	—
7 39 08 „	—	1	—	11 01 21 „	—	13	83
7 39 23 „	—	1	—	11 29 18 „	—	2	—
7 39 41 „	—	1	—	11 29 38 „	—	1	18
7 39 57 „	—	1	—	11 34 44 „	—	1	27
7 40 16 „	—	1	—	11 35 28 „ (1)	—	1	—
7 40 44 „	—	1	—	11 36 03 „	—	1	—
7 41 09 „	—	1	—	11 36 13 „	—	1	—
7 41 31 „	—	1	—	11 36 42 „	—	1	25
7 41 51 „	—	1	—	11 37 17 „	—	1	—
7 42 07 „	—	1	—	11 37 52 „	—	1	—
7 42 23 „	—	1	—	11 38 19 „	—	1	—
7 42 39 „	—	1	—	11 38 54 „	—	1	—
7 42 55 „	—	1	—	11 39 24 „	—	1	—
7 43 12 „	—	1	—	11 39 51 „	—	1	—
7 43 38 „	—	1	—	11 40 25 „	—	1	—
7 44 07 „	—	1	—	11 47 59 „	—	1	38
7 44 20 „	—	1	—	0 12 34 p.m.	—	1	23
7 44 36 „	—	1	—	0 13 02 „	—	1	—
7 44 52 „	—	1	—	0 13 15 „	—	2	—
7 45 12 „	—	1	—	0 13 38 „	—	1	35
7 45 32 „	—	1	—	0 14 24 „	—	1	—
7 45 52 „	—	1	—	0 14 38 „	—	1	—
7 46 06 „	—	1	—	0 15 08 „	—	1	30
7 46 25 „	—	1	—	0 15 52 „	—	1	29
7 47 02 „	—	1	—	0 16 55 „	—	1	17
7 47 24 „	—	1	—	0 34 26 „	2.2	4	—
7 48 12 „	—	1	—	0 34 51 „	—	4	30
7 48 51 „	—	1	—	0 53 57 „	0.85	1	25
7 50 11 „	—	1	30	1 48 40 „	—	1	13

(1): the disturbances were almost continuous between 11.35.28 and 11.40.25 a.m.; between 2.22.38 and 2.31.12 p.m.; between 5.14.46 and 5.18.04 p.m.; between 5.26.32 and 5.27.04 p.m.; and between 5.30.57 and 5.32.28 p.m.

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 14	sec.	μ	sec.	**AUG. 14**	sec.	μ	sec.
1 58 50 p.m.	—	1	16	5 12 52 p.m.	—	1	13
1 59 10 „	—	1	16	5 14 46 „	—	1	—
2 00 59 „	—	1	20	5 15 07 „	—	1	—
2 01 39 „	—	1	19	5 15 27 „	—	1	—
2 02 02 „	—	2	—	5 15 48 „	—	2	—
2 02 24 „	—	2	—	5 16 18 „	—	2	—
2 02 46 „	—	1	—	5 16 59 „	—	1	—
2 06 57 „	—	1	12	5 17 16 „	—	1	—
2 13 12 „	—	1	18	5 17 42 „	—	1	—
2 17 47 „	—	1	14	5 18 04 „	—	1	—
2 18 11 „	—	1	18	5 26 32 „	—	1	—
2 18 33 „	—	1	—	5 26 48 „	—	1	—
2 18 49 „	—	1	20	5 27 04 „	—	1	—
2 19 16 „	—	1	27	5 30 57 „	—	1	—
2 20 00 „	—	1	19	5 31 15 „	—	1	—
2 21 31 „	—	1	—	5 31 40 „	—	1	—
2 21 44 „	—	1	—	5 32 00 „	—	1	28
2 22 01 „	—	1	16	5 32 28 „	—	1	27
2 22 38 „	—	1	—	5 33 13 „	—	1	—
2 23 34 „	—	1	—	7 00 41 „	—	1	—
2 23 46 „	—	1	—	7 01 16 „	—	2	—
2 24 26 „	—	1	—	7 01 42 „	—	1	—
2 24 56 „	—	1	—	7 02 04 „	—	1	—
2 25 13 „	—	1	—	7 02 31 „	—	1	—
2 25 36 „	—	1	—	7 02 45 „	—	1	—
2 25 48 „	—	1	—	7 03 47 „	—	1	—
2 26 02 „	—	1	—	7 04 05 „	—	2	25
2 26 24 „	—	1	—	**AUG. 15**			
2 26 54 „	—	1	—	7 33 32 a.m.	1.2	4	18
2 27 24 „	—	1	—	8 02 07 „	—	1	30
2 28 23 „	—	1	—	8 04 38 „	2.5	2	29
2 28 40 „	—	1	—	9 52 40 „ (1)	—	2	—
2 28 53 „	—	1	—	9 53 02 „	—	1	—
2 29 22 „	—	1	—	9 53 20 „	—	1	—
2 29 35 „	—	1	—	9 53 49 „	—	1	—
2 29 59 „	—	1	—	9 54 12 „	—	2	—
2 30 24 „	—	1	—	9 54 35 „	—	1	—
2 31 12 „	—	1	—	9 55 13 „	—	1	—
2 33 19 „	—	1	12	9 55 38 „	—	1	—
3 49 03 „	—	3	20	9 56 03 „	—	1	—

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(1) The disturbances were almost continuous between 9.52.40 and 10.02.34 a.m. and between 3.58.20 and 4.07.36 p.m.

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 15	sec.	μ	sec.	**AUG. 15**	sec.	μ	sec.
9 56 44 a.m.	—	1	—	4 00 56 p.m.	—	9	—
9 56 58 ,,	—	1	—	4 01 18 ,,	—	6	—
9 57 19 ,,	—	1	—	4 01 31 ,,	—	23	—
9 57 51 ,,	—	1	—	4 01 48 ,,	—	27	—
9 58 28 ,,	—	1	—	4 02 24 ,,	—	2	—
9 58 56 ,,	—	1	—	4 02 46 ,,	—	12	—
9 59 52 ,, (1)	—	1	—	4 03 09 ,,	—	4	—
10 00 20 ,,	—	6	—	4 03 45 ,,	—	3	—
10 00 47 ,,	—	21	—	4 04 18 ,,	—	1	—
10 02 15 ,,	—	1	—	4 04 37 ,,	—	1	—
10 02 34 ,,	—	2	35	4 04 55 ,,	—	1	—
10 03 12 ,,	—	1	—	4 05 16 ,,	—	2	—
10 03 33 ,,	—	2	47	4 05 31 ,,	—	2	—
10 06 02 ,,	0.9	3	28	4 06 01 ,,	—	1	—
10 08 04 ,,	1.3	3	28	4 06 22 ,,	—	1	—
10 16 55 ,,	1.8	1	25	4 07 03 ,,	—	1	—
11 13 27 ,,	—	2	14	4 07 36 ,,	—	1	15
0 50 29 p.m.	0.85	2	18	4 33 51 ,,	—	1	29
2 28 45 ,,	0.94	2	34	4 36 42 ,,	1.3	1	21
2 29 23 ,,	—	1	11	4 44 31 ,,	—	1	17
3 04 34 ,,	—	1	10	4 45 02 ,,	—	1	19
3 34 18 ,,	—	1	11	4 48 47 ,, (2)	—	1	—
3 45 13 ,,	1.8	4	42	4 49 03 ,,	—	1	—
3 46 00 ,,	—	1	10	4 49 18 ,,	—	3	—
3 54 24 ,,	1.6	1	22	4 50 07 ,,	—	1	12
3 57 08 ,,	1.2	2	32	4 51 12 ,,	—	1	—
3 58 20 ,,	—	1	—	4 51 31 ,,	—	1	—
3 58 46 ,,	—	1	—	4 51 58 ,,	—	1	—
3 59 01 ,,	—	1	—	4 52 13 ,,	—	1	—
3 59 15 ,,	—	1	—	4 52 38 ,,	—	1	—
3 59 42 ,,	—	1	—	4 52 50 ,,	—	1	—
3 59 58 ,,	—	1	—	4 53 07 ,,	—	1	—
4 00 11 ,,	—	1	—	4 53 25 ,,	—	1	—
4 00 24 ,,	—	2	—	4 53 51 ,,	—	1	—
4 00 33 ,,	—	3	—	4 54 03 ,,	—	1	—

(1) At 9.59.11 am., there was a small sensible shock of max. 2a.=50μ, whose preliminary tremor lasted 0.44 sec.

(2) The disturbances were continuous between 4.48.47 and 4.59.14 p.m.; between 5.00.22 and 5.06.22 p.m.; between 5.08.54 and 5.13.16 p.m., etc.

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 15	sec.	μ	sec.	**AUG. 15**	sec.	μ	sec.
4 54 19 p.m.	—	1	—	5 12 41 p.m.	—	1	—
4 55 06 „	—	1	—	5 13 03 „	—	1	—
4 55 40 „	—	1	—	5 13 16 „	—	6	54
4 56 11 „	—	1	—	5 14 19 „	—	1	—
4 56 28 „	—	1	—	5 14 31 „	—	2	—
4 56 51 „	—	1	—	5 14 36 „	—	4	—
4 57 12 „	—	1	—	5 14 50 „	—	1	—
4 57 24 „	—	1	—	5 15 06 „	—	2	19
4 57 48 „	—	1	—	5 15 54 „	—	3	32
4 58 05 „	—	1	—	5 17 10 „	2.9	4	40
4 58 25 „	—	1	—	5 18 20 „	—	1	28
4 58 42 „	—	1	—	5 19 00 „	—	1	13
4 59 14 „	—	1	54	5 19 33 „	—	2	24
5 00 22 „	—	2	—	5 20 30 „	—	1	13
5 00 35 „	—	2	—	5 21 28 „	—	1	12
5 00 48 „	—	2	—	5 22 19 „	—	2	—
5 01 05 „	—	2	—	5 22 47 „	—	2	—
5 01 38 „	—	1	—	5 22 56 „	—	2	—
5 01 57 „	—	2	—	5 23 25 „	—	1	33
5 02 23 „	—	1	—	5 24 03 „	—	1	—
5 02 35 „	—	4	—	5 24 18 „	—	1	—
5 03 43 „	—	1	—	5 29 23 „	3.2	6	53
5 04 12 „	—	3	—	5 30 34 „	—	1	21
5 04 29 „	—	3	—	5 31 13 „	—	1	22
5 04 39 „	—	1	—	5 31 53 „	—	1	12
5 04 47 „	—	1	—	5 33 42 „	—	1	11
5 05 28 „	—	1	—	5 37 26 „	—	1	21
5 06 22 „	—	1	38	5 39 42 „	—	1	16
5 08 54 „ (1)	2.0	34	60	5 41 35 „	—	1	22
5 09 54 „	—	4	—	5 49 22 „	—	1	10
5 10 12 „	—	5	—	5 50 39 „	—	1	21
5 10 24 „	—	4	—	5 53 07 „	—	1	21
5 10 43 „	—	3	—	6 03 12 „	—	1	9
5 11 01 „	—	5	—	6 03 48 „	—	1	16
5 11 15 „	—	3	—	6 04 55 „	—	1	10
5 11 33 „	—	1	—	6 14 43 „	—	1	—
5 11 47 „	—	1	—	6 15 04 „	—	1	—
5 12 02 „	—	1	—	6 15 43 „	—	1	33
5 12 12 „	—	1	—	6 57 11 „	—	1	18
5 12 25 „	—	1	—	7 12 30 „	—	2	20

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(1) Lava fragments fell on the Maikake-yama slope.

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 15	sec.	μ	sec.
7 28 02 p.m.	—	3	—
7 28 50 ,,	—	1	27
7 30 05 ,,	—	1	60
7 32 21 ,,	—	1	51
7 38 34 ,,	—	1	45
7 40 37 ,,	—	1	36
7 42 28 ,,	—	2	30
7 43 47 ,,	—	1	30
7 52 50 ,,	—	2	22
AUG. 16			
4 26 37 a.m.	—	1	21
5 59 17 ,,	—	2	36
6 03 36 ,,	—	1	32
6 04 39 ,,	—	2	35
6 12 55 ,,	—	1	34
6 17 48 ,,	—	2	23
6 25 34 ,,	—	1	23
10 52 02 p.m.	—	2	30
11 31 44 ,,	—	2	15
11 48 29 ,,	—	1	18
AUG. 17			
1 54 58 a.m.	—	2	11
2 04 01 ,,	—	2	15
2 49 59 ,,	—	3	15
3 06 13 ,,	—	3	22
4 22 31 ,,	—	2	25
4 39 08 ,,	—	2	11
4 41 58 ,,	—	2	15
5 38 00 ,,	—	2	14
5 44 22 ,,	—	3	16
5 48 25 ,,	—	1	13
6 02 59 ,,	—	1	10
6 39 41 ,,	—	2	—
6 43 13 ,,	—	2	13
6 46 03 ,,	—	2	11
6 48 52 ,,	—	4	32
6 50 39 ,,	—	3	18
6 51 12 ,,	—	4	19
7 25 23 ,,	—	1	9
7 59 22 ,,	—	3	24
8 00 29 ,,	—	1	11
8 27 30 ,,	—	2	21
AUG. 17	sec.	μ	sec.
8 29 07 a.m.	—	2	13
8 29 20 ,,	—	3	20
8 42 30 ,,	—	2	13
8 42 43 ,,	—	2	—
8 43 01 ,,	—	1	—
8 44 30 ,,	—	2	18
8 44 48 ,,	—	2	29
8 45 25 ,,	—	2	18
8 53 25 ,,	—	2	10
8 59 39 ,,	—	2	14
9 00 06 ,,	—	1	25
9 00 31 ,,	—	3	75
9 02 03 ,,	—	3	31
9 04 38 ,,	—	2	9
9 16 27 ,,	—	2	12
9 35 39 ,,	—	1	15
9 36 40 ,,	—	1	15
9 38 20 ,,	—	2	14
9 42 54 ,,	—	1	20
9 43 57 ,,	—	1	—
9 44 33 ,,	—	1	—
9 45 21 ,,	—	1	—
10 17 55 ,,	—	1	14
11 48 28 ,,	—	1	18
0 05 07 p.m.	—	2	40
0 06 01 ,,	—	1	9
0 15 20 ,,	—	1	16
3 42 35 ,,	—	1	10
4 17 23 ,,	—	2	9
5 18 35 ,,	—	1	8
6 52 46 ,,	—	1	8
7 53 01 ,,	—	1	54
8 50 23 ,,	—	3	24
9 42 45 ,,	—	1	14
10 23 43 ,,	—	3	17
11 17 33 ,,	—	2	9
11 17 42 ,,	—	2	12
AUG. 18			
1 22 11 a.m.	—	1	4
2 38 27 ,,	—	2	28

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 18	sec.	μ	sec.
3 50 56 p.m.	—	1	25
AUG. 19			
3 05 13 a.m.	—	2	22
4 26 06 ,,	—	1	18
8 28 52 ,,	—	2	26
8 29 29 ,,	—	1	20
11 03 51 ,,	—	3	17
AUG. 20			
3 42 23 a.m.	—	3	46
4 07 10 ,,	—	2	10
5 30 30 ,,	—	1	27
6 50 28 p.m.	—	4	30
AUG. 21			
3 12 18 a.m.	—	4	32
1 31 42 p.m.	—	2	10
1 31 52 ,,	—	2	8
1 59 37 ,,	—	1	6
4 05 30 ,,	—	1	11
4 25 42 ,,	—	1	15
4 25 59 ,,	—	1	6
4 26 17 ,,	—	1	11
4 26 50 ,,	—	1	17
4 29 41 ,,	—	1	7
4 29 48 ,,	—	2	11
4 30 02 ,,	—	2	6
4 31 24 ,,	—	1	7
4 32 49 ,,	—	2	32
4 34 16 ,,	—	2	18
4 34 52 ,,	—	2	14
5 11 42 ,,	—	1	16
5 34 44 ,,	—	3	16
5 35 58 ,,	—	1	—
5 36 15 ,,	—	1	—
5 46 10 ,,	—	1	9
5 47 28 ,,	—	2	9
AUG. 21	sec.	μ	sec.
5 48 12 p.m.	—	1	16
AUG. 22			
10 29 38 a.m.	—	2	45
11 45 19 ,,	—	1	21
4 36 41 p.m.	—	1	18
4 37 38 ,,	—	2	12
5 17 51 ,,	—	2	27
9 07 27 ,,	—	2	34
AUG. 23			
9 22 31 a.m.	—	2	—
9 22 38 ,,	—	1	11
9 22 49 ,,	—	1	100
9 51 18 ,,	—	3	22
11 08 31 ,,	—	4	27
AUG. 24			
7 23 31 p.m.	—	2	24
8 37 31 ,, (1)	—	2	15
8 55 24 ,,	—	1	—
10 02 26 ,,	—	1	24
11 52 25 ,,	—	2	36
AUG. 25			
1 16 46 a.m.	—	2	36
2 01 09 ,,	—	1	90
3 21 54 ,,	—	1	28
5 30 45 ,,	—	1	19
9 11 18 ,,	—	3	34
11 50 35 ,,	—	3	57
6 25 42 p.m.	—	1	31
11 05 51 ,,	—	2	24
AUG. 26			
7 25 41 a.m.	—	1	46
10 15 21 ,,	—	2	34
0 46 38 p.m.	—	1	—
0 46 41 ,,	—	1	18
7 05 04 ,,	—	3	38
11 34 57 ,,	—	2	34
AUG. 27			
5 27 44 p.m.	—	2	18

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(1) At 8.40.25 p.m., there was felt a moderately strong earthquake shock of the Asama origin, which threw the writing index of the tromometers out of the recording smoked paper. Again, at 8.55.53 p.m. there was an unfelt shock of the following elements of motion :—Dur. prel. tremor = 0 sec., max. longitudinal 2a. = 33μ, total dur. = 4 sec.

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 27	sec.	μ	sec.	AUG. 27	sec.	μ	sec.
6 00 15 p.m.	—	2	20	8 14 43 p.m.	1.4	2	13
6 11 41 ,,	—	2	10	8 14 57 ,,	—	1	34
7 07 07 ,,	—	2	23	8 16 17 ,,	—	1	22
7 13 53 ,,	—	1	9	8 19 06 ,,	—	3	14
7 15 06 ,,	—	1	15	8 19 21 ,,	—	1	39
7 15 36 ,,	—	2	18	8 21 57 ,,	2.5	3	17
7 18 48 ,,	—	2	13	8 22 15 ,,	—	2	30
7 19 43 ,,	1.1	4	37	8 23 22 ,,	—	1	23
7 28 52 ,,	—	1	13	8 24 04 ,,	—	2	12
7 29 17 ,,	—	2	21	8 24 27 ,,	—	2	18
7 29 38 ,,	—	1	9	8 25 29 ,,	—	1	21
7 36 49 ,,	—	1	9	8 27 00 ,,	—	2	—
7 37 57 ,,	1.2	4	42	8 27 09 ,,	—	1	—
7 38 39 ,,	—	1	16	8 27 20 ,,	—	3	14
7 39 16 ,,	—	1	16	8 27 43 ,,	—	2	11
7 46 02 ,,	1.2	2	19	8 27 54 ,,	—	1	29
7 50 49 ,,	—	1	18	8 30 49 ,,	—	1	16
7 53 51 ,,	—	1	16	8 32 18 ,,	—	2	35
7 54 26 ,,	—	1	13	8 34 25 ,,	—	2	17
7 54 40 ,,	0.9	2	23	8 34 48 ,,	—	1	14
7 55 14 ,,	—	2	32	8 35 52 ,,	1.9	3	26
7 55 48 ,,	—	1	33	8 36 20 ,,	—	1	32
7 56 50 ,,	1.5	3	17	8 36 53 ,,	—	1	11
7 57 49 ,,	—	2	13	8 37 11 ,,	—	1	16
7 58 27 ,,	—	1	20	8 37 31 ,,	—	2	14
7 59 34 ,,	—	1	14	8 40 58 ,,	—	1	12
7 59 59 ,,	—	1	23	8 41 21 ,,	—	1	17
8 00 30 ,,	—	2	31	8 41 41 ,,	—	1	25
8 01 05 ,,	1.3	2	46	8 42 20 ,,	—	1	23
8 02 49 ,,	—	2	26	8 43 13 ,,	—	1	16
8 03 49 ,,	—	2	22	8 44 22 ,,	—	3	28
8 05 40 ,,	—	1	28	8 46 01 ,,	—	1	15
8 06 08 ,,	—	1	15	8 47 08 ,,	—	1	21
8 06 28 ,,	—	1	24	8 48 12 ,,	1.0	2	16
8 06 57 ,,	1.2	2	14	8 48 34 ,,	1.2	3	18
8 07 11 ,,	—	1	13	8 49 05 ,,	—	1	25
8 07 24 ,,	—	2	21	8 49 33 ,,	—	1	9
8 08 02 ,,	—	1	21	8 50 06 ,,	—	1	7
8 12 27 ,,	—	1	11	8 50 16 ,,	—	1	17
8 13 48 ,,	—	1	31	8 51 17 ,,	—	1	8

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 27	sec.	μ	sec.	**AUG. 27**	sec.	μ	sec.
8 51 27 p.m.	—	1	11	9 17 05 p.m.	—	1	21
8 52 34 ,,	—	2	21	9 17 26 ,,	—	3	21
8 53 18 ,,	—	1	17	9 17 52 ,,	—	2	—
8 54 10 ,,	—	2	13	9 18 30 ,,	—	2	33
8 54 23 ,,	—	1	16	9 19 14 ,,	—	2	14
8 54 39 ,,	—	2	—	9 19 28 ,,	—	2	24
8 55 10 ,,	—	2	23	9 20 12 ,,	—	1	24
8 55 33 ,,	—	1	21	9 20 42 ,,	—	4	18
8 55 59 ,,	—	1	21	9 21 00 ,,	—	3	27
8 56 42 ,,	—	2	41	9 21 27 ,,	—	2	30
8 57 36 ,,	—	2	18	9 22 57 ,,	—	1	28
8 59 44 ,,	—	2	21	9 23 31 ,,	—	2	—
9 00 10 ,,	—	3	35	9 24 06 ,,	—	2	12
9 00 45 ,,	—	2	9	9 24 20 ,,	—	2	33
9 00 54 ,,	—	2	32	9 25 54 ,,	—	1	—
9 01 31 ,,	—	2	25	9 26 17 ,,	—	1	—
9 01 56 ,,	—	3	32	9 26 28 ,,	—	1	18
9 02 28 ,,	—	1	12	9 28 27 ,,	—	1	—
9 03 16 ,,	—	3	30	9 28 38 ,,	—	1	12
9 03 46 ,,	—	2	38	9 30 05 ,,	—	2	35
9 04 24 ,,	—	2	36	9 30 50 ,,	—	2	—
9 05 03 ,,	—	2	31	9 31 08 ,,	—	1	11
9 05 35 ,,	—	1	13	9 31 22 ,,	—	1	—
9 06 26 ,,	—	2	19	9 31 32 ,,	—	1	17
9 06 49 ,,	—	1	24	9 32 36 ,,	—	1	15
9 07 19 ,,	—	3	—	9 33 18 ,,	—	2	18
9 07 31 ,,	—	3	19	9 34 52 ,,	—	2	—
9 07 50 ,,	—	1	35	9 35 09 ,,	—	2	—
9 08 25 ,,	—	1	22	9 35 26 ,,	—	1	14
9 08 47 ,,	—	1	15	9 36 12 ,,	—	2	16
9 09 22 ,,	—	2	39	9 36 30 ,,	—	2	19
9 10 01 ,,	—	3	20	9 37 07 ,,	—	4	—
9 10 31 ,,	—	4	30	9 37 33 ,,	—	2	17
9 11 26 ,,	—	2	14	9 39 50 ,,	—	2	28
9 12 02 ,,	—	1	13	9 40 34 ,,	—	1	14
9 12 54 ,,	—	4	35	9 42 11 ,,	—	3	35
9 13 31 ,,	—	2	15	9 43 42 ,,	—	2	26
9 14 06 ,,	—	4	33	9 44 22 ,,	—	3	—
9 16 04 ,,	—	3	25	9 44 42 ,,	—	3	26
9 16 29 ,,	—	1	15	9 45 15 ,,	—	2	20

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 27	sec.	μ	sec.	AUG. 27	sec.	μ	sec.
9 45 44 p.m.	—	3	28	10 18 35 p.m.	—	1	—
9 46 20 „	—	2	20	10 18 54 „	—	2	13
9 47 07 „	—	1	21	10 19 25 „	—	2	20
9 47 43 „	—	1	16	10 21 00 „	—	2	19
9 50 07 „	—	2	—	10 23 53 „	—	1	21
9 50 32 „	—	2	—	10 25 22 „	—	2	30
9 50 48 „	—	2	30	10 27 56 „	—	1	14
9 51 41 „	—	2	—	10 30 32 „	—	1	13
9 52 31 „	—	2	—	10 30 53 „	—	2	16
9 52 46 „	—	3	—	10 32 41 „	—	2	21
9 53 10 „	—	1	—	10 34 01 „	—	2	27
9 53 44 „	—	1	—	10 35 03 „	—	2	13
9 53 56 „	—	1	—	10 35 18 „	—	2	18
9 54 41 „	—	1	—	10 35 48 „	—	3	39
9 54 55 „	—	6	35	10 37 15 „	—	3	40
9 55 30 „	—	2	25	10 38 42 „	—	1	—
9 55 58 „	—	1	12	10 39 03 „	—	2	59
9 56 51 „	—	2	18	10 40 28 „	—	1	—
9 57 23 „	1.3	4	38	10 40 47 „	—	1	13
9 58 32 „	—	1	—	10 41 30 „	—	3	27
9 58 52 „	—	2	24	10 45 23 „	—	5	—
10 01 16 „	—	1	—	10 46 05 „	—	1	13
10 01 32 „	—	1	27	10 48 18 „	—	2	—
10 02 10 „	—	1	18	10 48 28 „	—	3	35
10 03 06 „	—	1	7	10 52 06 „	—	4	—
10 03 18 „	—	3	—	10 52 22 „	—	2	15
10 03 37 „	—	2	33	10 53 22 „	—	3	—
10 05 16 „	—	8	57	10 54 11 „	—	2	—
10 06 20 „	—	2	17	10 54 31 „	—	1	30
10 06 55 „	—	1	13	10 55 16 „	—	2	21
10 07 30 „	—	2	21	10 56 26 „	—	2	—
10 08 55 „	—	2	35	10 57 06 „	—	1	—
10 10 17 „	—	2	14	10 57 24 „	—	2	25
10 10 41 „	—	1	—	10 58 35 „	—	2	—
10 11 03 „	—	1	15	10 59 15 „	—	2	23
10 12 10 „	—	2	25	11 00 17 „	—	1	19
10 14 22 „	—	1	—	11 01 15 „	—	2	20
10 14 40 „	—	2	18	11 03 30 „	—	2	27
10 16 20 „	—	5	40	11 04 07 „	—	1	15
10 17 17 „	—	1	15	11 05 59 „	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 27	sec.	μ	sec.	**AUG. 28**	sec.	μ	sec.
11 06 20 p.m.	—	2	—	0 15 31 a.m.	—	1	18
11 06 51 ,,	—	2	14	0 18 11 ,,	—	1	16
11 11 05 ,,	—	1	43	0 18 46 ,,	—	2	—
11 12 18 ,,	—	1	17	0 19 16 ,,	1.1	9	—
11 13 45 ,,	—	3	34	0 19 54 ,,	—	2	—
11 15 15 ,,	—	1	—	0 20 32 ,,	—	4	50
11 15 46 ,,	—	2	—	0 21 44 ,,	—	1	25
11 16 19 ,,	—	3	43	0 22 36 ,,	—	1	17
11 17 15 ,,	—	2	30	0 23 04 ,,	—	2	30
11 18 09 ,,	—	2	29	0 23 51 ,,	—	2	19
11 19 36 ,,	—	1	20	0 27 55 ,,	—	1	15
11 20 27 ,,	—	1	20	0 29 25 ,,	—	1	23
11 23 35 ,,	—	1	19	0 31 05 ,,	—	1	10
11 25 38 ,,	—	4	39	0 33 26 ,,	—	1	26
11 27 20 ,,	—	2	—	0 34 25 ,,	—	2	—
11 27 39 ,,	—	1	17	0 34 54 ,,	—	1	—
11 37 42 ,,	—	2	—	0 35 18 ,,	—	1	33
11 38 00 ,,	—	1	30	0 36 05 ,,	—	2	—
11 39 19 ,,	—	1	21	0 36 33 ,,	—	2	35
11 39 53 ,,	—	2	36	0 37 24 ,,	—	2	31
11 41 07 ,,	—	1	15	0 40 35 ,,	—	1	24
11 42 24 ,,	—	1	24	0 43 06 ,,	—	3	26
11 44 31 ,,	—	2	22	0 45 48 ,,	—	2	23
11 48 59 ,,	—	1	17	0 47 15 ,,	—	1	20
11 49 38 ,,	—	2	25	0 48 50 ,,	—	1	18
11 50 29 ,,	—	1	25	0 50 28 ,,	—	2	22
11 52 18 ,,	—	1	18	0 52 15 ,,	—	2	—
11 57 07 ,,	—	2	44	0 52 49 ,,	—	1	21
AUG. 28				0 55 11 ,,	—	3	40
0 00 27 a.m.	—	2	37	0 58 24 ,,	—	1	15
0 01 12 ,,	—	1	47	1 00 06 ,,	—	1	31
0 05 50 ,,	—	2	22	1 03 03 ,,	—	1	19
0 07 12 ,,	—	2	18	1 03 36 ,,	—	1	18
0 08 24 ,,	—	2	44	1 04 03 ,,	—	1	—
0 09 45 ,,	—	3	31	1 04 18 ,,	—	1	29
0 11 22 ,,	—	1	24	1 05 33 ,,	—	1	—
0 12 56 ,,	—	2	26	1 05 55 ,,	—	1	19
0 13 53 ,,	—	1	12	1 06 27 ,,	—	1	15
0 14 33 ,,	—	2	21	1 06 58 ,,	—	1	22
0 15 09 ,,	—	2	20	1 09 14 ,,	—	1	27

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 28	sec.	μ	sec.
1 12 45 a.m.	—	1	—
1 13 06 ,,	—	1	—
1 13 30 ,,	—	1	21
1 15 13 ,,	—	1	—
1 15 31 ,,	—	1	—
1 15 55 ,,	—	1	24
1 17 03 ,,	—	1	—
1 17 16 ,,	—	1	12
1 18 27 ,,	—	1	34
1 19 44 ,,	—	1	32
1 22 34 ,,	—	1	13
1 25 26 ,,	—	9	—
1 26 38 ,,	—	2	—
1 27 20 ,,	—	4	—
1 27 46 ,,	—	5	—
1 28 20 ,,	—	2	—
1 28 47 ,,	—	2	—
1 29 06 ,,	—	2	—
1 29 27 ,,	—	1	18
1 29 55 ,,	—	2	—
1 30 13 ,,	—	2	—
1 30 35 ,,	—	4	43
1 32 03 ,,	—	2	—
1 32 15 ,,	—	2	22
1 32 55 ,,	—	2	—
1 33 23 ,,	—	3	—
1 33 47 ,,	—	3	—
1 34 25 ,,	—	1	21
1 34 51 ,,	—	1	—
1 35 11 ,,	—	2	—
1 35 40 ,,	—	4	—
1 36 12 ,,	—	3	—
1 36 42 ,,	—	2	—
1 37 06 ,,	—	1	21
1 37 32 ,,	—	1	—
1 37 56 ,,	—	1	—
1 38 14 ,,	—	4	—
1 38 34 ,,	—	3	—
1 38 51 ,,	—	1	—
1 39 11 ,,	—	2	—
AUG. 28	sec.	μ	sec.
1 39 31 a.m.	—	1	24
1 40 25 ,,	1.0	2	36
1 41 10 ,,	—	3	—
1 41 34 ,,	1.3	3	—
1 42 03 ,,	—	2	29
1 42 48 ,,	—	2	—
1 43 04 ,,	—	2	—
1 43 15 ,,	—	1	23
1 43 51 ,,	—	1	—
1 44 10 ,,	—	2	—
1 44 39 ,,	—	2	29
1 45 40 ,,	—	2	—
1 46 03 ,,	—	2	—
1 46 11 ,,	—	2	—
1 46 47 ,,	—	1	—
1 46 56 ,,	—	1	—
1 47 13 ,,	—	1	—
1 47 27 ,,	—	3	—
1 47 30 ,,	—	1	—
1 48 12 ,,	—	3	—
1 48 40 ,,	—	1	—
1 49 15 ,,	—	1	—
1 49 43 ,,	—	2	—
1 50 04 ,,	—	1	—
1 50 24 ,,	—	3	—
1 51 09 ,,	—	2	24
1 51 43 ,,	—	2	—
1 52 06 ,,	—	1	—
1 52 28 ,,	—	2	28
1 53 48 ,,	—	2	—
1 54 43 ,,	—	1	—
1 55 04 ,,	—	1	—
1 55 24 ,,	—	1	47
1 56 17 ,,	—	2	29
1 57 10 ,,	—	1	21
1 58 55 ,,	—	1	—
1 59 16 ,,	—	1	31
2 00 09 ,,	—	1	37
2 02 24 ,,	—	4	38
2 03 41 ,,	—	2	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 28	sec.	μ	sec.	**AUG. 28**	sec.	μ	sec.
2 04 22 a.m.	—	2	—	2 23 48 a.m.	—	2	—
2 04 37 ,,	—	1	—	2 24 28 ,,	—	3	—
2 05 24 ,,	—	1	—	2 25 10 ,,	—	2	—
2 05 55 ,,	—	13	—	2 25 22 ,,	—	9	—
2 06 29 ,,	—	10	—	2 26 22 ,,	—	5	—
2 06 47 ,,	—	4	—	2 26 40 ,,	—	2	—
2 07 18 ,,	—	2	—	2 26 57 ,,	—	4	—
2 07 41 ,,	—	2	—	2 27 29 ,,	—	2	—
2 08 32 ,,	—	2	—	2 27 44 ,,	—	2	—
2 09 08 ,,	—	3	—	2 28 20 ,,	—	2	—
2 09 38 ,,	—	2	—	2 28 44 ,,	—	3	—
2 10 19 ,,	—	2	—	2 28 54 ,,	—	2	—
2 10 34 ,,	—	13	—	2 29 21 ,,	—	2	—
2 10 43 ,,	—	8	—	2 29 48 ,,	—	3	—
2 11 06 ,,	—	2	—	2 30 19 ,,	—	2	—
2 11 23 ,,	—	2	—	2 30 39 ,,	—	1	—
2 11 39 ,,	—	2	—	2 30 58 ,,	—	2	—
2 12 03 ,,	—	1	—	2 31 17 ,,	—	2	—
2 12 20 ,,	—	2	—	2 31 31 ,,	—	2	—
2 12 23 ,,	—	7	—	2 32 16 ,,	—	1	—
2 13 01 ,,	—	2	—	2 32 42 ,,	—	2	—
2 13 27 ,,	—	2	36	2 33 25 ,,	—	5	—
2 14 11 ,,	—	1	22	2 33 49 ,,	—	3	—
2 14 57 ,,	—	2	—	2 34 25 ,,	—	2	—
2 16 02 ,,	—	1	—	2 34 50 ,,	—	3	28
2 16 17 ,,	—	16	—	2 35 30 ,,	—	2	—
2 16 45 ,,	—	4	—	2 36 18 ,,	—	2	—
2 17 14 ,,	—	6	—	2 36 43 ,,	—	3	—
2 18 02 ,,	—	2	—	2 37 18 ,,	—	4	—
2 18 28 ,,	—	3	—	2 37 33 ,,	—	1	—
2 18 52 ,,	—	10	—	2 38 16 ,,	—	3	—
2 19 26 ,,	—	12	—	2 38 37 ,,	—	2	—
2 20 12 ,,	—	2	—	2 38 46 ,,	—	2	—
2 21 08 ,,	—	1	—	2 39 07 ,,	—	2	—
2 21 39 ,,	—	1	—	2 39 20 ,,	—	3	—
2 21 51 ,,	—	1	—	2 39 34 ,,	—	6	—
2 22 06 ,,	—	2	—	2 40 19 ,,	—	2	—
2 22 18 ,,	—	8	—	2 40 59 ,,	—	4	—
2 23 09 ,,	—	1	—	2 41 09 ,,	—	2	—
2 23 17 ,,	—	1	—	2 41 17 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 28	sec.	μ	sec.	**AUG. 28**	sec.	μ	sec.
2 41 24 a.m.	—	2	—	3 00 17 a.m.	—	1	—
2 41 52 ,,	—	4	—	3 00 48 ,,	—	3	—
2 42 01 ,,	—	3	—	3 01 12 ,,	—	1	—
2 42 29 ,,	—	3	—	3 01 40 ,,	—	3	—
2 43 32 ,,	—	2	—	3 02 16 ,,	—	1	—
2 43 38 ,,	—	2	—	3 02 56 ,,	—	1	—
2 43 56 ,,	—	2	—	3 03 15 ,,	—	3	—
2 44 46 ,,	—	2	—	3 03 45 ,,	—	6	—
2 44 53 ,,	—	3	—	3 03 55 ,,	—	3	52
2 45 25 ,,	—	1	—	3 04 53 ,,	—	3	—
2 45 35 ,,	—	2	—	3 05 09 ,,	—	3	—
2 45 48 ,,	—	1	—	3 05 26 ,,	—	15	—
2 46 13 ,,	—	9	—	3 05 48 ,,	—	2	—
2 46 47 ,,	—	2	—	3 06 05 ,,	—	4	—
2 47 24 ,,	—	4	—	3 06 31 ,,	—	1	—
2 47 44 ,,	—	1	—	3 06 45 ,,	—	3	—
2 48 03 ,,	—	3	—	3 07 13 ,,	—	2	—
2 48 29 ,,	—	2	—	3 07 24 ,,	—	3	—
2 48 39 ,,	—	1	—	3 08 32 ,,	—	4	—
2 49 00 ,,	—	2	—	3 09 08 ,,	—	1	—
2 49 18 ,,	—	2	—	3 09 21 ,,	—	1	—
2 49 55 ,,	—	1	—	3 09 49 ,,	—	2	—
2 50 07 ,,	—	2	—	3 10 06 ,,	—	3	—
2 50 42 ,,	—	2	—	3 10 44 ,,	—	2	—
2 51 07 ,,	—	5	—	3 11 03 ,,	—	1	—
2 52 00 ,,	—	6	—	3 11 16 ,,	—	1	—
2 52 53 ,,	—	2	—	3 11 24 ,,	—	4	—
2 53 14 ,,	—	2	—	3 12 08 ,,	—	2	—
2 53 54 ,,	—	8	—	3 12 28 ,,	—	1	—
2 54 30 ,,	—	5	—	3 12 43 ,,	—	2	—
2 55 04 ,,	—	2	—	3 12 57 ,,	—	2	—
2 55 35 ,,	—	1	—	3 13 21 ,,	—	2	—
2 56 01 ,,	—	1	—	3 13 50 ,,	—	2	—
2 56 36 ,,	—	2	—	3 14 25 ,,	—	2	—
2 56 59 ,,	—	1	—	3 14 40 ,,	—	3	—
2 57 43 ,,	—	1	—	3 15 01 ,,	—	2	—
2 58 14 ,,	—	2	—	3 15 14 ,,	—	2	—
2 58 54 ,,	—	1	—	3 15 22 ,,	—	2	—
2 59 45 ,,	—	1	—	3 15 45 ,,	—	1	—
2 59 59 ,,	—	4	—	3 16 26 ,,	—	4	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 28	sec.	μ	sec.
3 16 56 a.m.	—	3	—
3 17 17 ,,	—	2	—
3 17 37 ,,	—	1	—
3 17 44 ,,	—	5	—
3 18 10 ,,	—	1	—
3 18 32 ,,	—	2	—
3 19 03 ,,	—	2	—
3 19 21 ,,	—	3	—
3 19 48 ,,	—	2	—
3 20 05 ,,	—	2	—
3 20 18 ,,	—	2	—
3 20 39 ,,	—	2	—
3 20 48 ,,	—	1	—
3 21 02 ,,	—	1	—
3 21 13 ,,	—	1	—
3 21 28 ,,	—	3	—
3 21 38 ,,	—	4	—
3 22 31 ,,	—	4	—
3 23 03 ,,	—	2	—
3 23 23 ,,	—	1	—
3 23 48 ,,	—	3	—
3 24 15 ,,	—	1	—
3 24 25 ,,	—	2	—
3 24 43 ,,	—	8	—
3 25 13 ,,	—	2	—
3 25 30 ,,	—	2	—
3 25 52 ,,	—	1	—
3 26 09 ,,	—	1	—
3 26 33 ,,	—	4	—
3 26 48 ,,	—	2	—
3 27 14 ,,	—	3	—
3 28 06 ,,	—	1	—
3 28 24 ,,	—	1	—
3 29 01 ,,	—	2	—
3 29 21 ,,	—	1	—
3 30 08 ,,	—	1	—
3 30 27 ,,	—	1	—
3 30 54 ,,	—	2	—
3 31 09 ,,	—	1	—
3 32 08 ,,	—	2	—
AUG. 28	sec.	μ	sec.
3 32 32 a.m.	—	2	—
3 32 54 ,,	—	1	—
3 33 09 ,,	—	1	—
3 33 29 ,,	—	1	40
3 34 30 ,,	—	1	—
3 34 46 ,,	—	2	—
3 35 02 ,,	—	1	—
3 35 14 ,,	—	2	—
3 35 44 ,,	—	2	—
3 35 51 ,,	—	2	—
3 36 30 ,,	—	1	—
3 36 36 ,,	—	2	—
3 36 53 ,,	—	3	—
3 37 12 ,,	—	1	28
3 37 49 ,,	—	1	—
3 37 55 ,,	—	1	—
3 38 03 ,,	—	3	—
3 38 21 ,,	—	2	—
3 38 42 ,,	—	2	—
3 38 49 ,,	—	1	—
3 39 09 ,,	—	3	—
3 39 27 ,,	—	2	—
3 40 18 ,,	—	2	—
3 40 37 ,,	—	2	—
3 41 04 ,,	—	1	—
3 41 17 ,,	—	3	—
3 41 38 ,,	—	1	—
3 41 48 ,,	—	2	—
3 42 00 ,,	—	4	—
3 42 14 ,,	—	2	—
3 42 30 ,,	—	2	—
3 42 48 ,,	—	2	—
3 43 04 ,,	—	1	—
3 43 17 ,,	—	1	—
3 43 26 ,,	—	1	—
3 43 37 ,,	—	3	—
3 44 00 ,,	—	1	—
3 44 12 ,,	—	1	—
3 44 17 ,,	—	1	—
3 44 34 ,,	—	2	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
AUG. 28	sec.	μ	sec.	**AUG. 28**	sec.	μ	sec.
3 44 52 a.m.	—	1	—	4 00 43 a.m.	—	1	—
3 45 12 ,,	—	3	—	4 00 55 ,,	—	2	—
3 45 34 ,,	—	1	—	4 01 36 ,,	—	1	—
3 46 41 ,,	—	3	—	4 01 52 ,,	—	3	—
3 46 49 ,,	—	2	—	4 02 33 ,,	—	4	—
3 47 01 ,,	—	15	—	4 03 11 ,,	—	4	—
3 47 31 ,,	—	1	—	4 03 32 ,,	—	3	—
3 47 57 ,,	—	3	—	4 03 51 ,,	—	2	—
3 48 14 ,,	—	2	—	4 04 20 ,,	—	2	21
3 48 35 ,,	—	2	—	4 04 50 ,,	—	1	—
3 48 57 ,,	—	1	—	4 05 07 ,,	—	1	19
3 49 08 ,,	—	2	—	4 06 05 ,,	—	3	—
3 49 14 ,,	—	2	—	4 06 21 ,,	—	1	31
3 49 32 ,,	—	1	—	4 07 06 ,,	—	3	—
3 49 39 ,,	—	2	—	4 07 25 ,,	—	1	19
3 49 57 ,,	—	2	—	4 07 55 ,,	—	1	20
3 50 12 ,,	—	2	—	4 08 45 ,,	—	1	—
3 50 24 ,,	—	1	—	4 09 04 ,,	—	1	26
3 50 35 ,,	—	1	—	4 09 56 ,,	—	2	59
3 50 47 ,,	—	1	—	4 11 11 ,,	—	1	20
3 51 03 ,,	—	1	—	4 11 48 ,,	—	2	30
3 51 58 ,,	—	1	—	4 12 45 ,,	—	2	—
3 52 15 ,,	—	2	—	4 12 59 ,,	—	3	21
3 52 53 ,,	—	2	38	4 13 25 ,,	—	1	19
3 53 37 ,,	—	1	—	4 14 15 ,,	—	2	—
3 53 55 ,,	—	2	—	4 14 36 ,,	—	2	22
3 54 17 ,,	—	4	—	4 15 02 ,,	—	2	32
3 54 51 ,,	—	3	—	4 17 00 ,,	—	1	—
3 55 02 ,,	—	2	—	4 17 09 ,,	—	1	—
3 55 11 ,,	—	2	—	4 17 20 ,,	—	1	—
3 55 35 ,,	—	2	37	4 18 07 ,,	—	1	17
3 56 25 ,,	—	2	—	4 18 59 ,,	—	1	—
3 57 02 ,,	—	1	—	4 19 23 ,,	—	1	—
3 57 36 ,,	—	2	—	4 19 49 ,,	—	1	—
3 58 10 ,,	—	1	—	4 20 00 ,,	—	1	—
3 58 33 ,,	—	7	—	4 20 40 ,,	—	1	25
3 58 59 ,,	—	2	—	4 21 08 ,,	—	12	—
3 59 25 ,,	—	13	—	4 21 32 ,,	—	2	—
4 00 07 ,,	—	2	—	4 21 47 ,,	—	1	—
4 00 18 ,,	—	1	—	4 22 04 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 28	sec.	μ	sec.	AUG. 28	sec.	μ	sec.
4 22 24 a.m.	—	1	—	4 50 23 a.m.	—	1	—
4 22 33 „	—	1	—	4 50 53 „	—	1	—
4 22 49 „	—	1	—	4 53 02 „	—	1	—
4 23 26 „	—	2	31	4 53 51 „	—	1	—
4 23 59 „	—	1	—	4 55 50 „	—	1	—
4 28 16 „	—	1	—	4 56 55 „	—	1	—
4 28 40 „	—	1	—	4 57 19 „	—	1	—
4 30 10 „	—	1	—	4 58 57 „	—	1	—
4 33 34 „	—	12	—	5 00 47 „	—	1	16
4 34 30 „	—	2	—	5 04 45 „	—	1	—
4 34 52 „	—	2	—	5 07 29 „	—	1	—
4 35 55 „	—	1	—	5 07 50 „	—	1	—
4 36 08 „	—	1	—	5 08 38 „	—	1	—
4 37 09 „	—	13	—	5 15 02 „	—	1	29
4 37 23 „	—	3	—	5 15 44 „	—	1	16
4 37 50 „	—	2	—	5 16 52 „	—	1	—
4 38 19 „	—	1	—	5 18 51 „	—	4	—
4 38 36 „	—	1	—	5 19 09 „	—	2	18
4 39 00 „	—	1	—	5 20 02 „	—	1	18
4 39 12 „	—	1	—	5 22 29 „	—	1	—
4 39 47 „	—	1	—	5 22 41 „	—	1	—
4 40 31 „	—	1	—	5 22 55 „	—	2	16
4 40 45 „	—	1	—	5 23 15 „	—	1	24
4 41 01 „	—	1	—	5 24 32 „	—	1	19
4 41 16 „	—	1	—	5 25 08 „	—	1	19
4 41 50 „	—	1	—	5 25 33 „	—	2	44
4 41 59 „	—	1	—	5 26 32 „	—	1	18
4 42 20 „	—	1	—	5 27 11 „	—	1	40
4 43 10 „	—	1	—	5 28 20 „	—	1	13
4 43 29 „	—	1	—	5 28 40 „	—	1	25
4 44 05 „	—	1	—	5 31 51 „	—	1	20
4 45 02 „	—	2	—	5 33 54 „	—	1	18
4 45 20 „	—	1	—	5 34 32 „	—	1	28
4 47 07 „	—	1	—	5 35 00 „	—	1	—
4 47 23 „	—	1	—	5 35 10 „	—	1	—
4 47 48 „	—	2	—	5 36 19 „	—	1	17
4 47 51 „	—	1	—	5 37 16 „	—	1	—
4 48 00 „	—	1	—	5 38 12 „	—	1	15
4 48 49 „	—	1	—	5 41 38 „	—	1	—
4 49 51 „	—	1	—	6 21 41 „	—	1	11

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
AUG. 28	sec.	μ	sec.
6 29 54 a.m.	—	2	34
0 03 44 p.m.	—	2	18
6 55 28 ,,	—	2	16
8 34 54 ,,	—	3	25
AUG. 29			
3 22 35 ,,	—	2	35
AUG. 30			
3 57 34 a.m.	—	2	27
4 13 13 ,,	—	1	23
4 14 35 ,,	—	1	24
7 11 02 p.m.	—	2	22
AUG. 31			
8 29 33 a.m.	—	2	26
9 13 03 ,,	—	2	11
9 18 43 ,,	—	2	22
9 22 45 ,,	—	1	—
9 22 53 ,,	—	1	—
9 23 02 ,,	—	2	—
AUG. 31	sec.	μ	sec.
3 26 29 p.m.	—	2	14
3 29 17 ,,	—	2	31
3 33 00 ,,	—	2	19
3 33 23 ,,	—	2	21
5 28 17 ,,	—	5	35
5 38 41 ,,	—	1	15
5 39 09 ,,	—	1	17
5 40 33 ,,	—	1	18
5 41 30 ,,	—	1	26
5 44 45 ,,	—	2	23
5 45 45 ,,	—	1	21
6 38 31 ,,	—	1	13
6 38 50 ,,	—	1	19
10 57 30 ,,	—	3	25

TABLE I, c. LIST OF THE ASAMA VOLCANIC OUTBURSTS INSTRUMENTALLY REGISTERED AT THE ASHINO-TAIRA (ASAMA-YAMA) SEISMOLOGICAL STATION.

SEPT. 1ST—2ND, 1913.

ALL THE DISTURBANCES CONTAINED IN THIS TABLE WERE OF THE [B] TYPE, BEING THE SHAKINGS CAUSED BY THE ERUPTIVE DISTURBANCES.

(2a denotes the maximum longitudinal motion, in micron.)

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
SEPT. 1	sec.	μ	sec.	**SEPT. 1**	sec.	μ	sec.
1 58 59 a.m.	—	2	26	9 21 05 p.m.	—	2	45
8 45 50 p.m.	—	1	—	9 22 23 ,,	—	2	—
8 52 50 ,,	—	1	34	9 22 51 ,,	—	2	28
8 53 56 ,,	—	1	—	9 24 05 ,,	—	2	—
9 00 01 ,,	—	1	—	9 24 49 ,,	—	2	—
9 01 14 ,,	—	1	—	9 26 24 ,,	—	2	25
9 03 51 ,,	—	1	30	9 27 29 ,,	—	2	—
9 05 24 ,,	—	1	45	9 28 34 ,,	—	1	—
9 06 41 ,,	—	1	17	9 29 06 ,,	—	2	35
9 07 46 ,,	—	1	—	9 30 11 ,,	—	1	—
9 08 41 ,,	—	2	—	9 30 36 ,,	—	2	—
9 09 11 ,,	—	1	—	9 31 10 ,,	—	1	—
9 09 36 ,,	—	2	—	9 31 35 ,,	—	2	—
9 10 11 ,,	—	2	—	9 32 39 ,,	—	2	—
9 10 24 ,,	—	2	—	9 32 53 ,,	—	2	—
9 10 52 ,,	—	2	—	9 33 31 ,,	—	2	—
9 11 10 ,,	—	2	—	9 34 12 ,,	—	2	—
9 11 52 ,,	—	2	—	9 35 02 ,,	—	2	—
9 12 18 ,,	—	2	26	9 35 44 ,,	—	2	—
9 13 05 ,,	—	2	36	9 36 21 ,,	—	2	52
9 13 45 ,,	—	1	—	9 37 21 ,,	—	2	26
9 14 03 ,,	—	2	—	9 37 59 ,,	—	2	23
9 14 53 ,,	—	2	18	9 38 40 ,,	—	3	—
9 16 23 ,,	—	2	—	9 39 05 ,,	—	3	—
9 17 10 ,,	—	3	—	9 40 30 ,,	—	3	—
9 17 42 ,,	—	2	31	9 40 34 ,,	—	2	—
9 18 42 ,,	—	1	—	9 40 47 ,,	—	2	—
9 19 10 ,,	—	2	—	9 41 16 ,,	—	3	29
9 19 34 ,,	—	2	24	9 41 54 ,,	—	2	—
9 20 13 ,,	—	2	—	9 42 19 ,,	—	2	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
SEPT. 1	sec.	μ	sec.
9 42 40 p.m.	—	2	—
9 43 05 ,,	—	2	—
9 44 02 ,,	—	1	—
9 44 29 ,,	—	2	—
9 44 49 ,,	—	2	—
9 45 09 ,,	—	2	20
9 46 20 ,,	—	2	—
9 46 45 ,,	—	3	18
9 47 42 ,,	—	1	—
9 48 30 ,,	—	2	—
9 48 49 ,,	—	2	—
9 49 11 ,,	—	3	30
9 50 27 ,,	—	3	—
9 51 15 ,,	—	2	—
9 51 44 ,,	—	2	—
9 52 35 ,,	—	3	—
9 53 02 ,,	—	1	—
9 53 49 ,,	—	3	43
9 54 41 ,,	—	2	—
9 54 58 ,,	—	2	—
9 55 50 ,,	—	2	—
9 56 10 ,,	—	2	—
9 57 33 ,,	—	1	—
9 58 07 ,,	—	3	—
9 58 48 ,,	—	2	—
9 59 26 ,,	—	2	—
10 00 07 ,,	—	2	—
10 00 53 ,,	—	2	—
10 01 04 ,,	—	4	26
10 01 43 ,,	—	2	—
10 02 01 ,,	—	3	—
10 02 21 ,,	—	3	—
10 02 59 ,,	—	4	24
10 03 34 ,,	—	3	—
10 04 01 ,,	—	2	—
10 04 39 ,,	—	5	—
10 05 17 ,,	—	2	—
10 05 50 ,,	—	3	—
10 06 40 ,,	—	2	—
10 07 20 ,,	—	2	—
SEPT. 1	sec.	μ	sec.
10 07 43 p.m.	—	5	—
10 08 22 ,,	—	4	—
10 08 44 ,,	—	3	—
10 09 11 ,,	—	2	—
10 09 47 ,,	—	3	—
10 10 35 ,,	—	4	—
10 11 05 ,,	—	3	—
10 12 00 ,,	—	4	—
10 12 24 ,,	—	4	—
10 12 54 ,,	—	4	—
10 13 41 ,,	—	2	—
10 14 27 ,,	—	3	—
10 14 54 ,,	—	3	—
10 15 17 ,,	—	3	—
10 15 57 ,,	—	5	—
10 17 14 ,,	—	3	—
10 18 19 ,,	—	3	—
10 18 42 ,,	—	2	—
10 19 04 ,,	—	3	—
10 19 32 ,,	—	3	—
10 20 13 ,,	—	3	—
10 20 38 ,,	—	3	—
10 21 50 ,,	—	2	—
10 22 18 ,,	—	3	—
10 22 53 ,,	—	3	—
10 23 28 ,,	—	2	—
10 23 57 ,,	—	2	—
10 24 27 ,,	—	3	—
10 25 23 ,,	—	3	—
10 26 06 ,,	—	3	—
10 27 01 ,,	—	2	—
10 27 41 ,,	—	2	—
10 27 58 ,,	—	2	—
10 28 30 ,,	—	2	—
10 29 10 ,,	—	6	—
10 29 53 ,,	—	4	—
10 30 17 ,,	—	2	—
10 30 40 ,,	—	3	—
10 31 38 ,,	—	3	—
10 32 28 ,,	—	4	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
SEPT. 1	sec.	μ	sec.
10 33 09 p.m.	—	3	—
10 33 39 ,,	—	3	—
10 33 59 ,,	—	3	—
10 34 20 ,,	—	3	—
10 34 41 ,,	—	6	—
10 35 04 ,,	—	4	—
10 35 30 ,,	—	3	—
10 36 02 ,,	—	3	—
10 36 47 ,,	—	3	—
10 37 12 ,,	—	2	—
10 38 02 ,,	—	3	—
10 38 27 ,,	—	5	—
10 38 48 ,,	—	3	—
10 39 36 ,,	—	3	—
10 39 52 ,,	—	4	—
10 40 35 ,,	—	2	—
10 41 00 ,,	—	6	—
10 41 47 ,,	—	2	—
10 42 21 ,,	—	2	—
10 43 18 ,,	—	2	—
10 43 41 ,,	—	2	—
10 44 26 ,,	—	2	—
10 45 13 ,,	—	7	—
10 46 06 ,,	—	2	—
10 46 52 ,,	—	2	—
10 47 23 ,,	—	3	—
10 48 15 ,,	—	3	—
10 49 05 ,,	—	3	—
10 49 20 ,,	—	3	—
10 50 11 ,,	—	2	—
10 50 39 ,,	—	2	—
10 51 09 ,,	—	4	—
10 52 15 ,,	—	2	—
10 53 11 ,,	—	2	—
10 54 01 ,,	—	2	—
10 54 33 ,,	—	3	—
10 55 27 ,,	—	4	—
10 57 17 ,,	—	2	—
10 57 35 ,,	—	2	—
10 57 54 ,,	—	3	—
SEPT. 1	sec.	μ	sec.
10 58 47 p.m.	—	3	—
10 59 39 ,,	—	2	—
11 00 31 ,,	—	2	—
11 01 07 ,,	—	3	—
11 02 11 ,,	—	2	—
11 03 02 ,,	—	2	—
11 03 39 ,,	—	2	—
11 04 22 ,,	—	2	—
11 04 45 ,,	—	2	—
11 05 25 ,,	—	4	—
11 06 04 ,,	—	2	—
11 06 29 ,,	—	4	—
11 07 09 ,,	—	4	—
11 07 29 ,,	—	2	—
11 08 38 ,,	—	4	—
11 09 33 ,,	—	4	—
11 10 29 ,,	—	3	—
11 11 10 ,,	—	3	—
11 12 26 ,,	—	2	—
11 12 57 ,,	—	2	—
11 13 18 ,,	—	3	—
11 13 51 ,,	—	2	—
11 14 25 ,,	—	2	—
11 15 31 ,,	—	2	—
11 16 00 ,,	—	2	—
11 16 29 ,,	—	2	—
11 17 33 ,,	—	3	—
11 18 16 ,,	—	3	—
11 19 10 ,,	—	2	—
11 20 00 ,,	—	2	—
11 20 33 ,,	—	3	—
11 20 58 ,,	—	2	—
11 21 17 ,,	—	4	—
11 21 57 ,,	—	3	—
11 22 36 ,,	—	3	—
11 23 39 ,,	—	6	—
11 24 30 ,,	—	4	—
11 24 55 ,,	—	2	—
11 25 29 ,,	—	2	—
11 26 22 ,,	—	2	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
SEPT. 1	sec.	μ	sec.
11 26 47 p.m.	—	2	—
11 27 40 ,,	—	2	—
11 28 44 ,,	—	2	—
11 29 14 ,,	—	2	—
11 29 49 ,,	—	2	—
11 30 31 ,,	—	2	—
11 31 03 ,,	—	2	—
11 32 26 ,,	—	2	—
11 33 05 ,,	—	3	—
11 33 42 ,,	—	2	—
11 34 09 ,,	—	2	—
11 34 45 ,,	—	2	—
11 35 30 ,,	—	2	—
11 36 41 ,,	—	2	—
11 37 20 ,,	—	1	—
11 37 52 ,,	—	2	—
11 39 19 ,,	—	2	—
11 40 07 ,,	—	2	—
11 41 42 ,,	—	1	—
11 42 33 ,,	—	2	—
11 44 12 ,,	—	2	—
11 46 28 ,,	—	2	—
11 47 39 ,,	—	2	—
11 48 14 ,,	—	2	—
11 48 55 ,,	—	1	—
11 49 46 ,,	—	2	—
11 50 48 ,,	—	2	—
11 51 59 ,,	—	2	—
11 53 25 ,,	—	2	—
11 54 26 ,,	—	2	—
11 55 01 ,,	—	2	—
11 56 08 ,,	—	1	—
11 57 17 ,,	—	2	—
11 58 40 ,,	—	2	—
11 59 32 ,,	—	2	—
SEPT. 2			
0 00 05 a.m.	—	2	—
0 00 22 ,,	—	2	—
0 01 16 ,,	—	1	—
0 01 40 ,,	—	1	—
0 02 15 ,,	—	1	—
SEPT. 2	sec.	μ	sec.
0 03 06 a.m.	—	1	—
0 03 55 ,,	—	3	39
0 08 12 ,,	—	7	92
0 11 24 ,,	—	2	—
0 12 00 ,,	—	1	—
0 12 30 ,,	—	4	—
0 12 59 ,,	—	5	—
0 13 25 ,,	—	2	—
0 13 54 ,,	—	1	—
0 14 15 ,,	—	2	—
0 14 41 ,,	—	4	—
0 15 28 ,,	—	2	—
0 16 03 ,,	—	2	—
0 16 41 ,,	—	2	—
0 17 04 ,,	—	2	—
0 17 56 ,,	—	1	—
0 18 24 ,,	—	2	—
0 18 51 ,,	—	1	—
0 19 20 ,,	—	2	—
0 19 54 ,,	—	2	—
0 20 37 ,,	—	1	—
0 22 33 ,,	—	1	—
0 23 39 ,,	—	1	—
0 24 15 ,,	—	2	—
0 24 34 ,,	—	3	—
0 25 32 ,,	—	3	43
0 27 31 ,,	—	1	—
0 28 19 ,,	—	2	—
0 29 08 ,,	—	1	—
0 29 48 ,,	—	2	—
0 30 35 ,,	—	2	—
0 31 24 ,,	—	2	—
0 32 11 ,,	—	3	—
0 33 01 ,,	—	2	—
0 33 27 ,,	—	3	—
0 34 05 ,,	—	4	—
0 34 37 ,,	—	5	—
0 35 08 ,,	—	2	—
0 35 31 ,,	—	5	—
0 36 33 ,,	—	4	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
SEPT. 2	sec.	μ	sec.	**SEPT. 2**	sec.	μ	sec.
0 36 56 a.m.	—	2	—	0 58 33 a.m.	—	2	—
0 37 21 ,,	—	1	—	0 59 00 ,,	—	1	—
0 38 14 ,,	—	3	—	0 59 37 ,,	—	1	—
0 38 33 ,,	—	2	—	1 00 17 ,,	—	2	—
0 39 08 ,,	—	3	—	1 00 51 ,,	—	2	—
0 39 42 ,,	—	3	—	1 01 04 ,,	—	4	—
0 40 00 ,,	—	5	—	1 02 00 ,,	—	5	—
0 40 31 ,,	—	4	—	1 02 40 ,,	—	3	—
0 41 24 ,,	—	2	—	1 03 47 ,,	—	6	—
0 41 44 ,,	—	2	—	1 04 24 ,,	—	8	—
0 42 06 ,,	—	6	—	1 05 11 ,,	—	3	—
0 43 01 ,,	—	5	—	1 05 37 ,,	—	3	—
0 43 37 ,,	—	5	—	1 06 04 ,,	—	2	—
0 44 11 ,,	—	6	—	1 06 26 ,,	—	3	—
0 44 42 ,,	—	2	—	1 07 12 ,,	—	3	—
0 45 17 ,,	—	1	—	1 07 44 ,,	—	3	—
0 45 51 ,,	—	5	—	1 08 18 ,,	—	5	—
0 46 07 ,,	—	4	—	1 08 54 ,,	—	2	—
0 46 34 ,,	—	3	—	1 09 24 ,,	—	2	—
0 47 04 ,,	—	7	—	1 10 21 ,,	—	2	—
0 47 33 ,,	—	3	—	1 10 49 ,,	—	2	—
0 48 00 ,,	—	4	—	1 11 24 ,,	—	2	—
0 48 31 ,,	—	8	—	1 12 23 ,,	—	4	—
0 49 12 ,,	—	7	—	1 13 03 ,,	—	2	—
0 49 48 ,,	—	5	—	1 14 02 ,,	—	11	39
0 50 21 ,,	—	6	—	1 14 55 ,,	—	10	38
0 50 45 ,,	—	7	—	1 15 34 ,,	—	6	—
0 51 18 ,,	—	5	—	1 15 51 ,,	—	2	—
0 51 45 ,,	—	2	—	1 16 32 ,,	—	3	—
0 52 27 ,,	—	2	—	1 16 45 ,,	—	4	—
0 52 36 ,,	—	3	—	1 17 23 ,,	—	3	—
0 53 14 ,,	—	4	—	1 17 42 ,,	—	5	—
0 53 43 ,,	—	2	—	1 18 13 ,,	—	2	—
0 54 04 ,,	—	3	—	1 18 28 ,,	—	3	—
0 54 23 ,,	—	2	—	1 18 40 ,,	—	3	—
0 54 51 ,,	—	1	—	1 19 02 ,,	—	2	—
0 55 48 ,,	—	5	—	1 19 24 ,,	—	2	—
0 56 34 ,,	—	2	—	1 19 44 ,,	—	7	—
0 57 03 ,,	—	4	—	1 20 23 ,,	—	4	—
0 57 42 ,,	—	3	—	1 20 48 ,,	—	5	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
SEPT. 2	sec.	μ	sec.	SEPT. 2	sec.	μ	sec.
1 21 23 a.m.	—	2	—	1 46 36 a.m.	—	2	—
1 21 41 ,,	—	4	—	1 47 00 ,,	—	2	—
1 22 12 ,,	—	4	—	1 47 39 ,,	—	3	17
1 22 42 ,,	—	4	—	1 48 47 ,,	—	4	52
1 23 48 ,,	—	2	—	1 49 42 ,,	—	5	43
1 24 20 ,,	—	12	—	1 50 30 ,,	—	4	27
1 24 45 ,,	—	7	—	1 51 06 ,,	—	4	62
1 25 02 ,,	—	2	—	1 52 22 ,,	—	7	—
1 25 25 ,,	—	9	—	1 52 46 ,,	—	4	—
1 25 53 ,,	—	4	—	1 53 10 ,,	—	6	—
1 26 28 ,,	—	2	—	1 53 30 ,,	—	3	—
1 27 03 ,,	—	6	—	1 53 57 ,,	—	3	20
1 27 41 ,,	—	6	—	1 54 27 ,,	—	3	—
1 28 10 ,,	—	7	—	1 54 38 ,,	—	3	—
1 28 54 ,,	—	6	—	1 55 22 ,,	—	4	23
1 29 20 ,,	—	7	—	1 55 57 ,,	—	4	—
1 30 00 ,,	—	4	—	1 56 22 ,,	—	5	—
1 30 17 ,,	—	4	—	1 56 53 ,,	—	4	—
1 31 15 ,,	—	5	—	1 57 11 ,,	—	4	—
1 31 58 ,,	—	7	—	1 57 56 ,,	—	3	—
1 33 58 ,,	—	2	—	1 58 19 ,,	—	3	—
1 36 00 ,,	—	3	—	1 58 53 ,,	—	2	—
1 36 28 ,,	—	13	—	1 59 20 ,,	—	4	29
1 37 40 ,,	—	2	—	2 00 07 ,,	—	2	—
1 38 08 ,,	—	3	—	2 00 23 ,,	—	3	—
1 38 36 ,,	—	2	—	2 01 00 ,,	—	6	—
1 38 58 ,,	—	2	—	2 01 25 ,,	—	5	—
1 39 19 ,,	—	2	—	2 01 52 ,,	—	10	—
1 39 50 ,,	—	2	—	2 02 22 ,,	—	4	—
1 40 30 ,,	—	1	—	2 02 47 ,,	—	4	—
1 41 02 ,,	—	2	—	2 03 42 ,,	—	2	—
1 41 30 ,,	—	2	—	2 04 05 ,,	—	6	—
1 41 45 ,,	—	2	—	2 04 35 ,,	—	3	—
1 42 13 ,,	—	3	—	2 04 47 ,,	—	2	—
1 43 06 ,,	—	2	—	2 05 02 ,,	—	4	—
1 43 34 ,,	—	3	—	2 05 36 ,,	—	5	19
1 44 29 ,,	—	2	—	2 06 12 ,,	—	2	—
1 44 59 ,,	—	3	—	2 06 36 ,,	—	7	—
1 45 29 ,,	—	2	—	2 07 00 ,,	—	4	—
1 45 52 ,,	—	2	—	2 07 33 ,,	—	2	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
SEPT. 2	sec.	μ	sec.	**SEPT. 2**	sec.	μ	sec.
2 07 53 a.m.	—	2	—	2 38 10 a.m.	—	2	—
2 08 12 ,,	—	2	—	2 38 23 ,,	—	10	—
2 08 45 ,,	—	2	—	2 39 17 ,,	—	2	—
2 09 04 ,,	—	6	—	2 39 44 ,,	—	7	36
2 09 33 ,,	—	3	—	2 41 01 ,,	—	2	15
2 10 15 ,,	—	2	—	2 41 51 ,,	—	8	—
2 10 35 ,,	—	3	—	2 42 19 ,,	—	4	—
2 10 48 ,,	—	3	—	2 42 47 ,,	—	3	—
2 11 08 ,,	—	3	—	2 43 16 ,,	—	4	26
2 11 27 ,,	—	3	—	2 44 19 ,,	—	2	—
2 12 07 ,,	—	6	—	2 44 39 ,,	—	2	26
2 12 32 ,,	—	2	—	2 45 37 ,,	—	2	—
2 12 47 ,,	—	4	—	2 47 10 ,,	—	6	38
2 13 22 ,,	—	7	—	2 48 12 ,,	—	1	—
2 13 48 ,,	—	3	44	2 49 14 ,,	—	3	—
2 20 27 ,,	—	2	26	2 49 44 ,,	—	7	—
2 21 28 ,,	5.1	43	—	2 50 18 ,,	—	4	—
2 22 26 ,,	—	3	—	2 50 44 ,,	—	2	—
2 22 57 ,,	—	2	—	2 51 54 ,,	—	13	90
2 23 13 ,,	—	2	—	2 54 07 ,,	—	2	—
2 24 10 ,,	—	1	—	2 54 36 ,,	—	3	—
2 26 45 ,,	—	2	—	2 55 18 ,,	—	1	—
2 27 33 ,,	—	1	—	2 56 20 ,,	—	2	—
2 27 57 ,,	—	1	—	2 57 02 ,,	—	2	—
2 28 20 ,,	—	2	—	2 57 41 ,,	—	4	20
2 28 42 ,,	—	2	—	2 58 08 ,,	—	2	—
2 29 48 ,,	—	3	—	2 58 29 ,,	—	4	—
2 30 57 ,,	—	1	—	2 59 33 ,,	—	2	—
2 31 13 ,,	—	2	—	3 00 28 ,,	—	2	—
2 31 58 ,,	—	2	—	3 01 21 ,,	—	1	—
2 32 37 ,,	—	2	—	3 01 43 ,,	—	2	—
2 33 26 ,,	—	1	—	3 02 22 ,,	—	3	—
2 33 44 ,,	—	3	—	3 02 57 ,,	—	4	—
2 34 10 ,,	—	2	—	3 03 29 ,,	—	5	—
2 34 47 ,,	—	7	—	3 03 55 ,,	—	2	—
2 35 12 ,,	—	2	—	3 04 19 ,,	—	2	—
2 35 57 ,,	7.8	7	—	3 04 35 ,,	—	2	—
2 36 46 ,,	—	2	—	3 04 56 ,,	—	2	—
2 37 14 ,,	—	1	—	3 05 28 ,,	—	2	—
2 37 41 ,,	—	2	—	3 06 32 ,,	—	3	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
SEPT. 2	sec.	μ	sec.	**SEPT. 2**	sec.	μ	sec.
3 07 19 a.m.	—	2	—	3 33 19 a.m.	—	3	—
3 07 35 ,,	—	2	—	3 34 14 ,,	—	4	—
3 08 15 ,,	—	2	—	3 35 12 ,,	—	2	—
3 08 56 ,,	—	4	—	3 35 41 ,,	—	2	—
3 09 29 ,,	—	2	—	3 35 58 ,,	—	2	—
3 09 53 ,,	—	2	—	3 36 43 ,,	—	2	—
3 10 14 ,,	—	2	—	3 37 27 ,,	—	2	—
3 10 51 ,,	—	2	—	3 37 48 ,,	—	2	—
3 11 13 ,,	—	3	—	3 38 29 ,,	—	1	—
3 11 44 ,,	—	2	—	3 38 43 ,,	—	3	—
3 12 12 ,,	—	2	—	3 39 01 ,,	—	4	—
3 12 53 ,,	—	2	—	3 40 01 ,,	—	3	—
3 13 40 ,,	—	1	—	3 40 31 ,,	—	6	—
3 14 34 ,,	—	1	—	3 41 02 ,,	—	2	—
3 14 58 ,,	—	3	32	3 41 26 ,,	—	4	—
3 15 35 ,,	—	3	31	3 41 45 ,,	—	2	—
3 16 12 ,,	—	2	—	3 42 21 ,,	—	1	—
3 16 46 ,,	—	2	—	3 42 57 ,,	—	1	—
3 17 15 ,,	—	2	—	3 43 37 ,,	—	2	—
3 17 35 ,,	—	4	—	3 43 56 ,,	—	3	—
3 18 08 ,,	—	4	—	3 44 21 ,,	—	1	—
3 18 32 ,,	—	3	—	3 44 47 ,,	—	1	—
3 19 21 ,,	—	4	—	3 45 20 ,,	—	3	39
3 19 59 ,,	—	3	—	3 46 08 ,,	—	4	—
3 20 57 ,,	—	2	—	3 46 43 ,,	—	6	—
3 21 26 ,,	—	6	—	3 47 21 ,,	—	2	—
3 21 58 ,,	—	2	—	3 47 45 ,,	—	2	—
3 23 03 ,,	—	2	—	3 48 30 ,,	—	2	—
3 24 17 ,,	—	1	—	3 50 01 ,,	—	3	34
3 25 05 ,,	—	2	—	3 51 03 ,,	—	4	—
3 25 44 ,,	—	1	—	3 51 41 ,,	—	1	—
3 26 26 ,,	—	2	—	3 52 06 ,,	—	2	—
3 27 43 ,,	—	1	—	3 52 53 ,,	—	2	—
3 28 32 ,,	—	2	53	3 53 12 ,,	—	2	—
3 29 46 ,,	—	2	—	3 53 26 ,,	—	2	—
3 30 45 ,,	—	2	36	3 54 00 ,,	—	2	—
3 31 43 ,,	—	4	—	3 54 39 ,,	—	1	—
3 32 11 ,,	—	2	—	3 55 20 ,,	—	2	—
3 32 29 ,,	—	2	—	3 55 43 ,,	—	1	—
3 32 55 ,,	—	2	—	3 56 02 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
SEPT. 2	sec.	μ	sec.	**SEPT. 2**	sec.	μ	sec.
3 56 43 a.m.	—	1	—	5 43 28 a.m.	—	2	—
3 57 13 ,,	—	2	—	5 44 01 ,,	—	2	—
3 58 04 ,,	—	2	—	5 44 28 ,,	—	1	—
3 58 46 ,,	—	2	—	5 45 01 ,,	—	2	—
3 59 34 ,,	—	1	—	5 45 36 ,,	—	2	—
3 59 54 ,,	—	1	—	5 46 54 ,,	—	5	—
4 00 05 ,,	—	2	—	5 47 10 ,,	—	2	—
4 00 49 ,,	—	2	—	5 47 25 ,,	—	2	—
4 01 02 ,,	—	2	—	5 49 09 ,,	—	3	—
4 01 43 ,,	—	1	—	5 49 38 ,,	—	3	—
4 02 15 ,,	—	5	—	5 50 07 ,,	—	3	—
4 02 43 ,,	—	2	—	5 50 29 ,,	—	2	—
4 03 53 ,,	—	2	—	5 50 44 ,,	—	3	—
4 04 09 ,,	—	2	31	5 51 38 ,,	—	3	—
4 04 45 ,,	—	1	—	5 52 16 ,,	—	1	—
4 05 02 ,,	—	1	—	5 53 07 ,,	—	4	—
4 07 13 ,,	—	1	—	5 53 36 ,,	—	3	—
4 08 12 ,,	—	1	—	5 54 24 ,,	—	3	—
4 10 16 ,,	—	1	—	5 55 24 ,,	—	7	—
4 12 08 ,,	—	1	—	5 56 06 ,,	—	3	—
4 13 18 ,,	—	1	—	5 57 07 ,,	—	3	—
4 24 04 ,,	—	2	18	5 57 30 ,,	—	3	—
4 36 09 ,,	—	1	—	5 57 47 ,,	—	2	—
4 44 30 ,,	—	2	22	5 58 36 ,,	—	2	—
4 54 26 ,,	—	2	22	5 59 26 ,,	—	4	—
5 26 11 ,,	—	1	32	5 59 58 ,,	—	2	—
5 27 28 ,,	—	2	32	6 00 36 ,,	—	3	—
5 30 22 ,,	—	1	16	6 01 07 ,,	—	4	—
5 31 16 ,,	—	1	—	6 01 57 ,,	—	2	33
5 32 41 ,,	—	2	—	6 02 39 ,,	—	2	—
5 33 17 ,,	—	2	27	6 03 15 ,,	—	3	—
5 34 04 ,,	—	2	12	6 04 19 ,,	—	2	—
5 34 23 ,,	—	1	—	6 05 19 ,,	—	2	—
5 34 45 ,,	—	2	29	6 05 57 ,,	—	2	—
5 35 51 ,,	—	2	45	6 06 13 ,,	—	2	—
5 37 08 ,,	—	2	34	6 06 52 ,,	—	5	—
5 40 34 ,,	—	2	—	6 07 20 ,,	—	2	—
5 41 01 ,,	—	2	56	6 07 50 ,,	—	2	—
5 42 26 ,,	—	5	—	6 08 37 ,,	—	1	—
5 43 00 ,,	—	2	—	6 09 44 ,,	—	2	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
SEPT. 2	sec.	μ	sec.
6 10 46 a.m.	—	2	—
6 11 11 ”	—	2	—
6 11 34 ”	—	6	—
6 12 05 ”	—	3	—
6 12 53 ”	—	2	—
6 13 15 ”	—	2	—
6 13 42 ”	—	1	—
6 14 33 ”	—	1	—
6 15 33 ”	—	1	—
6 15 59 ”	—	1	—
6 16 46 ”	—	2	49
6 18 03 ”	—	1	—
6 18 17 ”	—	2	23
6 19 09 ”	—	4	53
6 21 36 ”	2.6	3	44
6 22 35 ”	—	2	39
6 24 41 ”	—	2	38
6 26 03 ”	—	1	—
6 26 29 ”	—	2	33
6 28 03 ”	—	1	—
SEPT. 2	sec.	μ	sec.
6 28 29 a.m.	—	1	—
6 30 12 ”	—	2	27
6 30 44 ”	—	1	24
6 36 14 ”	—	2	—
6 37 03 ”	—	2	—
6 38 07 ”	—	2	—
6 39 15 ”	—	2	—
6 40 15 ”	—	2	—
6 42 34 ”	—	2	—
6 44 46 ”	—	1	—
6 46 30 ”	—	2	—
6 48 14 ”	—	2	33
6 50 34 ”	—	2	54
6 51 46 ”	—	2	35

TABLE I, D. LIST OF THE ASAMA VOLCANIC DISTURBANCES INSTRUMENTALLY REGISTERED AT THE ASHINO-TAIRA (ASAMA-YAMA) SEISMOLOGICAL STATION.

SEPT. 2ND TO OCT. 12TH, 1913.

4

[A]....VOLCANIC EARTHQUAKE NOT ACCOMPANIED BY ERUPTION.
[B]....EARTH-SHAKING CAUSED BY VOLCANIC ERUPTION.

(2a denotes the maximum range of motion, in micron.)

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	Max. 2a.		Total Duration.	Character.
		Longitudinal.	Transverse		
SEPT. 2	sec.	μ	μ	sec.	
6 59 25 a.m.	—	3	2	24	B
7 00 57 „	—	2	2	34	„
7 01 35 „	—	1	1	26	„
7 03 28 „	—	1	2	24	„
7 04 11 „	—	2	2	34	„
7 06 17 „	—	1	1	22	„
7 07 57 „	—	3	3	36	„
7 08 34 „	—	2	3	31	„
7 09 12 „	—	2	3	23	„
7 09 36 „	—	2	2	24	„
7 10 43 „	—	2	2	21	„
7 11 08 „	—	2	2	36	„
7 13 05 „	—	2	2	33	„
7 14 33 „	—	1	2	21	„
7 15 35 „	—	—	1	24	„
7 18 50 „	—	4	3	35	„
7 27 56 „	—	2	2	22	„
7 30 30 „	—	2	2	19	„
7 31 09 „	—	2	2	31	„
7 31 56 „	—	2	2	14	„
7 37 38 „	—	2	2	23	„
7 52 24 „	—	2	3	22	„
10 39 28 „	—	4	4	45	„
10 48 28 „	—	3	2	24	„
11 17 57 „	—	2	1	16	„
11 35 48 „	—	3	3	18	„
SEPT. 3					
8 44 19 a.m.	—	1	1	20	„
8 44 49 „	—	1	1	—	„
8 46 18 „	—	4	3	41	„

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	Max. 2a.		Total Duration.	Character.
		Longitudinal.	Transverse.		
	sec.	μ	μ	sec.	
SEPT. 4 6 51 05 a.m.	—	2	2	39	B
SEPT. 7 7 25 49 p.m.	1.8	10	—	—	A
SEPT. 13 9 32 56 p.m.	2.8	—	3	53	,,
SEPT. 21 1 45 03 a.m.	1.8	18	—	13	,,
1 50 59 p.m.	0.49	93	64	97	B (Strong explosion.)
SEPT. 27 9 04 15 p.m.	1.2	34	—	14	A
OCT. 7 11 32 33 a.m.	—	4	3	35	B {Accompanied by rushing sounds.}
OCT. 9 1 09 10 a.m.	0.52	18	8	70	,, (Strong explosion.)
OCT. 12 8 25 52 a.m.	0.7	113	165	112	A (Sensible shock.)

TABLE I, E. LIST OF THE ASAMA VOLCANIC OUTBURSTS INSTRUMENTALLY REGISTERED AT THE ASHINO-TAIRA (ASAMA-YAMA) SEISMOLOGICAL STATION.

OCT. 15TH TO 22ND, 1913.

ALL THE DISTURBANCES CONTAINED IN THIS TABLE WERE OF THE [B] TYPE, BEING THE SHAKINGS CAUSED BY THE VOLCANIC OUTBURSTS.

(2a denotes the maximum longitudinal range of motion, in micron.)

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
OCT. 15	sec.	μ	sec.	OCT. 15	sec.	μ	sec.
2 41 49 a.m.	—	1	25	4 14 47 a.m.	—	2	—
3 02 37 „	—	1	15	4 15 03 „	—	1	18
3 16 29 „	—	2	19	4 15 42 „	—	1	14
3 18 35 „	—	1	26	4 16 55 „	—	1	16
3 25 40 „	—	2	19	4 17 49 „	—	1	15
3 32 31 „	—	2	24	4 18 27 „	—	1	—
3 36 15 „	—	2	20	4 18 31 „	—	1	21
3 36 52 „	—	1	16	4 19 12 „	—	2	—
3 41 25 „	—	2	—	4 19 29 „	—	1	—
3 41 40 „	—	1	—	4 19 55 „	—	1	—
3 41 55 „	—	1	—	4 20 27 „	—	1	25
3 42 15 „	—	1	—	4 20 52 „	—	2	19
3 46 32 „	—	1	—	4 21 38 „	—	2	22
3 47 05 „	—	1	—	4 22 43 „	—	1	12
3 59 15 „	—	1	12	4 23 29 „	—	1	13
4 00 39 „	—	2	22	4 23 53 „	—	1	12
4 04 44 „	—	3	—	4 25 59 „	—	2	17
4 05 05 „	—	2	—	4 27 30 „	—	1	—
4 05 41 „	—	2	14	4 27 36 „	—	1	14
4 06 57 „	—	1	18	4 27 52 „	—	2	15
4 08 04 „	—	2	—	4 30 09 „	—	2	23
4 08 59 „	—	2	—	4 33 42 „	—	2	28
4 09 39 „	—	1	—	4 37 02 „	—	2	18
4 10 21 „	—	3	25	4 38 42 „	—	1	22
4 11 52 „	—	2	—	4 39 53 „	—	3	—
4 12 32 „	—	1	—	4 40 17 „	—	1	—
4 12 57 „	—	2	—	4 40 30 „	—	1	—
4 13 22 „	—	2	—	4 40 43 „	—	2	—
4 13 47 „	—	1	11	4 40 57 „	—	1	—
4 14 15 „	—	1	—	4 41 02 „	—	2	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
OCT. 15	sec.	μ	sec.	OCT. 15	sec.	μ	sec.
4 41 12 a.m.	—	2	—	5 09 19 a.m.	—	2	—
4 41 25 ,,	—	1	—	5 09 24 ,,	—	1	29
4 41 49 ,,	—	2	—	5 10 29 ,,	—	2	24
4 42 08 ,,	—	5	—	5 11 44 ,,	—	2	22
4 42 55 ,,	—	2	—	5 13 42 ,,	—	3	21
4 44 00 ,,	—	3	—	5 14 49 ,,	—	2	15
4 45 02 ,,	—	3	—	5 16 29 ,,	—	1	17
4 45 19 ,,	—	1	—	5 17 42 ,,	—	2	—
4 45 29 ,,	—	1	—	5 17 59 ,,	—	2	30
4 45 45 ,,	—	2	—	5 21 52 ,,	—	2	25
4 45 49 ,,	—	1	—	5 22 30 ,,	—	1	22
4 46 44 ,,	—	1	—	5 23 59 ,,	—	1	15
4 48 32 ,,	—	1	19	5 24 45 ,,	—	1	23
4 49 35 ,,	—	1	—	5 25 30 ,,	—	1	—
4 50 01 ,,	—	3	—	5 25 42 ,,	—	1	26
4 50 30 ,,	—	2	15	5 27 14 ,,	—	1	21
4 51 25 ,,	—	1	22	5 28 18 ,,	—	1	22
4 52 20 ,,	—	1	32	5 28 59 ,,	—	1	21
4 53 48 ,,	—	2	22	5 29 28 ,,	—	2	—
4 56 15 ,,	—	1	—	5 30 00 ,,	—	3	—
4 56 30 ,,	—	1	—	5 30 12 ,,	—	4	—
4 56 53 ,,	—	1	—	5 30 55 ,,	—	3	—
4 58 09 ,,	—	1	21	5 32 17 ,,	—	3	—
4 59 12 ,,	—	1	19	5 33 56 ,,	—	4	—
4 59 32 ,,	—	2	19	5 37 30 ,,	—	1	—
5 00 07 ,,	—	1	26	5 37 38 ,,	—	4	—
5 00 47 ,,	—	1	22	5 37 50 ,,	—	3	—
5 01 59 ,,	—	1	—	5 38 53 ,,	—	2	—
5 02 22 ,,	—	1	12	5 39 30 ,,	—	1	—
5 03 14 ,,	—	1	24	5 39 42 ,,	—	2	—
5 03 48 ,,	—	2	20	5 39 52 ,,	—	1	15
5 04 59 ,,	—	3	21	5 40 57 ,,	—	1	—
5 06 17 ,,	—	3	—	5 41 29 ,,	—	2	26
5 06 25 ,,	—	2	—	5 43 10 ,,	—	3	41
5 06 42 ,,	—	3	31	5 44 24 ,,	—	1	—
5 07 14 ,,	—	1	—	5 44 50 ,,	—	2	28
5 07 22 ,,	—	2	—	5 46 14 ,,	—	2	23
5 07 52 ,,	—	1	—	5 46 55 ,,	—	1	17
5 08 23 ,,	—	2	—	5 47 33 ,,	—	2	—
5 08 45 ,,	—	2	21	5 47 42 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
OCT. 15	sec.	μ	sec.	OCT. 15	sec.	μ	sec.
5 48 00 a.m.	—	1	18	6 15 22 a.m.	—	2	29
5 50 15 „	—	4	—	6 15 53 „	—	3	—
5 50 57 „	—	2	24	6 16 30 „	—	1	35
5 51 25 „	—	2	—	6 17 38 „	—	2	—
5 52 09 „	—	2	—	6 18 24 „	—	1	—
5 52 14 „	—	3	—	6 19 19 „	—	3	48
5 52 30 „	—	1	—	6 21 49 „	—	1	—
5 53 02 „	—	2	—	6 22 10 „	—	1	30
5 53 28 „	—	2	—	6 23 10 „	—	2	49
5 54 13 „	—	4	—	6 24 02 „	—	2	—
5 54 55 „	—	3	—	6 25 09 „	—	2	50
5 55 38 „	—	3	22	6 28 42 „	—	1	31
5 56 55 „	—	3	—	6 31 51 „	—	1	42
5 57 30 „	—	4	29	6 32 49 „	—	2	38
5 58 02 „	—	3	30	6 34 02 „	—	1	11
5 58 55 „	—	2	—	6 34 25 „	—	2	—
5 59 38 „	—	2	—	6 34 41 „	—	1	25
6 00 07 „	—	2	33	6 35 14 „	—	1	—
6 00 53 „	—	2	—	6 35 30 „	—	1	18
6 01 19 „	—	2	49	6 36 19 „	—	2	44
6 02 14 „	—	2	39	6 41 54 „	—	2	39
6 03 05 „	—	2	—	6 44 44 „	—	2	53
6 04 07 „	—	2	—	6 46 20 „	—	2	—
6 05 09 „	—	2	—	6 46 44 „	—	1	—
6 05 58 „	—	2	—	6 47 13 „	—	1	—
6 06 19 „	—	1	—	6 47 29 „	—	1	—
6 06 42 „	—	2	—	6 48 18 „	—	2	—
6 07 14 „	—	1	—	6 48 45 „	—	1	—
6 07 29 „	—	1	—	6 48 56 „	—	1	41
6 07 40 „	—	2	—	6 50 29 „	—	2	—
6 08 18 „	—	3	—	6 50 48 „	—	2	—
6 08 50 „	—	2	—	6 51 07 „	—	2	—
6 09 30 „	—	2	—	6 51 30 „	—	2	46
6 10 38 „	—	1	—	6 53 34 „	—	3	—
6 11 04 „	—	1	—	6 54 25 „	—	6	—
6 11 47 „	—	1	31	6 55 19 „	—	2	—
6 12 22 „	—	1	—	6 55 30 „	—	2	—
6 13 09 „	—	1	—	6 55 56 „	—	3	47
6 13 32 „	—	1	40	6 58 03 „	—	1	38
6 14 18 „	—	2	—	6 59 31 „	—	2	41

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
OCT. 15	sec.	μ	sec.	OCT. 15	sec.	μ	sec.
7 00 42 a.m.	—	2	33	7 30 52 a.m.	—	2	50
7 01 33 ,,	—	2	—	7 32 13 ,,	—	2	31
7 02 29 ,,	—	2	—	7 32 53 ,,	—	2	30
7 02 40 ,,	—	2	24	7 34 14 ,,	—	1	41
7 03 36 ,,	—	2	—	7 35 42 ,,	—	2	—
7 04 21 ,,	—	2	—	7 36 19 ,,	—	1	31
7 04 59 ,,	—	1	—	7 37 06 ,,	—	2	31
7 05 27 ,,	—	1	—	7 37 54 ,,	—	2	—
7 06 16 ,,	—	2	—	7 38 19 ,,	—	1	18
7 07 02 ,,	—	1	—	7 39 26 ,,	—	1	21
7 07 19 ,,	—	1	—	7 40 22 ,,	—	2	23
7 07 57 ,,	—	2	—	7 48 10 ,,	—	1	—
7 08 30 ,,	—	1	24	7 49 22 ,,	—	4	—
7 10 06 ,,	—	6	—	7 49 51 ,,	—	2	25
7 10 39 ,,	—	2	—	7 53 34 ,,	—	2	26
7 11 13 ,,	—	2	—	7 56 56 ,,	—	3	35
7 11 56 ,,	—	1	—	7 57 55 ,,	—	2	—
7 12 43 ,,	—	1	21	7 58 49 ,,	—	4	31
7 14 15 ,,	—	2	—	8 00 44 ,,	—	1	—
7 14 45 ,,	—	2	—	8 01 09 ,,	—	2	—
7 15 31 ,,	—	1	—	8 02 34 ,,	—	3	44
7 16 10 ,,	—	1	—	8 03 58 ,,	—	2	—
7 17 12 ,,	—	2	—	8 04 21 ,,	—	2	31
7 17 55 ,,	—	2	29	8 07 36 ,,	—	2	—
7 18 30 ,,	—	1	—	8 08 19 ,,	—	2	26
7 18 51 ,,	—	2	—	8 11 05 ,,	—	2	—
7 19 32 ,,	—	6	—	8 11 26 ,,	—	2	28
7 20 19 ,,	—	1	—	8 13 25 ,,	—	2	—
7 20 35 ,,	—	3	—	8 13 58 ,,	—	3	38
7 21 08 ,,	—	3	—	8 15 06 ,,	—	2	20
7 21 42 ,,	—	1	—	8 15 50 ,,	—	2	35
7 22 17 ,,	—	2	27	8 17 45 ,,	—	2	—
7 23 08 ,,	—	2	38	8 18 03 ,,	—	2	27
7 23 59 ,,	—	2	45	8 18 47 ,,	—	2	21
7 25 39 ,,	—	2	38	8 19 16 ,,	—	2	34
7 26 45 ,,	—	2	50	8 20 04 ,,	—	3	—
7 27 37 ,,	—	3	39	8 20 26 ,,	—	2	—
7 29 09 ,,	—	1	—	8 21 17 ,,	—	2	—
7 29 42 ,,	—	2	—	8 21 39 ,,	—	2	36
7 30 35 ,,	—	3	—	8 22 24 ,,	—	2	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
OCT. 15	sec.	μ	sec.	**OCT. 15**	sec.	μ	sec.
8 22 49 a.m.	—	1	—	8 53 35 a.m.	—	2	33
8 23 16 ,,	—	1	—	8 54 14 ,,	—	2	—
8 23 28 ,,	—	2	33	8 54 27 ,,	—	2	37
8 24 04 ,,	—	1	—	8 55 23 ,,	—	2	—
8 24 19 ,,	—	1	—	8 55 48 ,,	—	2	—
8 24 40 ,,	—	2	—	8 56 03 ,,	—	2	—
8 25 04 ,,	—	2	—	8 56 40 ,,	—	1	—
8 25 33 ,,	—	3	—	8 57 15 ,,	—	2	19
8 26 21 ,,	—	2	—	8 57 43 ,,	—	2	35
8 26 39 ,,	—	2	47	8 58 46 ,,	—	2	—
8 27 26 ,,	—	1	—	9 00 17 ,,	—	2	39
8 29 42 ,,	—	2	31	9 01 01 ,,	—	2	—
8 30 16 ,,	—	2	—	9 01 30 ,,	—	1	—
8 31 40 ,,	—	2	—	9 02 11 ,,	—	2	—
8 32 48 ,,	—	2	24	9 03 03 ,,	—	3	57
8 33 57 ,,	—	2	41	9 04 06 ,,	—	3	—
8 35 11 ,,	—	2	54	9 04 49 ,,	—	2	—
8 36 13 ,,	—	2	—	9 06 11 ,,	—	2	—
8 37 40 ,,	—	3	41	9 06 33 ,,	—	2	—
8 38 29 ,,	—	3	—	9 07 26 ,,	—	2	—
8 39 12 ,,	—	2	—	9 08 08 ,,	—	2	—
8 39 58 ,,	—	2	—	9 09 05 ,,	—	1	—
8 40 45 ,,	—	3	52	9 09 37 ,,	—	2	—
8 41 46 ,,	—	3	38	9 10 01 ,,	—	2	—
8 42 38 ,,	—	2	—	9 11 05 ,,	—	2	—
8 43 07 ,,	—	1	—	9 11 46 ,,	—	2	—
8 43 26 ,,	—	2	—	9 12 31 ,,	—	2	—
8 44 20 ,,	—	2	—	9 13 32 ,,	—	1	—
8 44 47 ,,	—	2	27	9 14 00 ,,	—	2	—
8 45 50 ,,	—	2	40	9 14 40 ,,	—	2	—
8 46 48 ,,	—	2	—	9 15 07 ,,	—	2	—
8 47 44 ,,	—	2	31	9 15 33 ,,	—	2	—
8 48 22 ,,	—	2	21	9 16 12 ,,	—	2	—
8 49 04 ,,	—	2	36	9 17 26 ,,	—	2	—
8 49 43 ,,	—	2	—	9 17 58 ,,	—	3	—
8 50 13 ,,	—	2	—	9 18 30 ,,	—	2	—
8 51 38 ,,	—	2	—	9 18 46 ,,	—	2	—
8 51 51 ,,	—	2	—	9 19 01 ,,	—	2	—
8 52 25 ,,	—	2	—	9 19 21 ,,	—	2	—
8 53 03 ,,	—	2	—	9 19 49 ,,	—	2	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
OCT. 15	sec.	μ	sec.	**OCT. 15**	sec.	μ	sec.
9 20 16 a.m.	—	1	—	9 43 06 a.m.	—	3	—
9 20 31 ,,	—	2	—	9 43 49 ,,	—	3	—
9 21 21 ,,	—	1	—	9 44 26 ,,	—	2	—
9 21 53 ,,	—	1	—	9 45 12 ,,	—	2	—
9 22 06 ,,	—	2	—	9 45 48 ,,	—	1	—
9 22 27 ,,	—	2	—	9 46 17 ,,	—	2	—
9 23 18 ,,	—	2	—	9 47 01 ,,	—	1	—
9 24 20 ,,	—	2	—	9 47 56 ,,	—	2	—
9 25 02 ,,	—	2	—	9 48 39 ,,	—	3	—
9 25 50 ,,	—	2	—	9 49 07 ,,	—	2	—
9 26 11 ,,	—	1	—	9 50 08 ,,	—	2	—
9 26 47 ,,	—	1	—	9 50 26 ,,	—	3	—
9 27 02 ,,	—	2	—	9 51 05 ,,	—	4	41
9 27 20 ,,	—	2	—	9 52 23 ,,	—	1	—
9 27 52 ,,	—	1	—	9 52 42 ,,	—	4	—
9 28 35 ,,	—	2	—	9 53 22 ,,	—	3	—
9 28 58 ,,	—	2	—	9 53 56 ,,	—	3	—
9 29 12 ,,	—	2	—	9 54 14 ,,	—	3	—
9 29 33 ,,	—	2	—	9 54 53 ,,	—	1	—
9 30 06 ,,	—	2	—	9 55 27 ,,	—	2	—
9 30 38 ,,	—	2	—	9 55 47 ,,	—	2	—
9 31 23 ,,	—	2	—	9 56 19 ,,	—	2	—
9 32 07 ,,	—	2	—	9 56 44 ,,	—	2	—
9 32 46 ,,	—	2	—	9 57 40 ,,	—	1	—
9 33 36 ,,	—	2	—	9 58 04 ,,	6.8	3	27
9 34 10 ,,	—	2	—	9 58 42 ,,	—	2	—
9 34 41 ,,	—	2	—	9 59 40 ,,	—	3	—
9 35 19 ,,	—	1	—	10 00 15 ,,	—	3	—
9 35 50 ,,	—	2	—	10 01 16 ,,	—	2	—
9 36 23 ,,	6.9	4	—	10 02 02 ,,	—	1	—
9 36 46 ,,	—	2	—	10 02 51 ,,	—	2	—
9 37 10 ,,	—	2	—	10 03 06 ,,	—	3	34
9 37 36 ,,	—	2	—	10 03 51 ,,	—	2	—
9 38 23 ,,	—	2	—	10 04 08 ,,	—	2	—
9 38 57 ,,	—	2	—	10 04 30 ,,	—	3	—
9 39 23 ,,	—	2	32	10 04 50 ,,	—	2	—
9 40 24 ,,	—	2	—	10 05 25 ,,	—	2	—
9 41 00 ,,	—	2	—	10 06 35 ,,	—	2	—
9 41 50 ,,	—	2	—	10 06 47 ,,	—	3	—
9 42 30 ,,	—	2	—	10 07 16 ,,	—	2	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
OCT. 15	sec.	μ	sec.	OCT. 15	sec.	μ	sec.
10 07 55 a.m.	—	1	—	10 34 32 a.m.	—	1	—
10 08 28 ,,	—	2	—	10 35 34 ,,	—	2	—
10 09 11 ,,	—	2	—	10 36 31 ,,	—	2	33
10 09 51 ,,	—	1	—	10 37 20 ,,	—	3	—
10 10 09 ,,	—	4	30	10 37 45 ,,	—	1	—
10 11 07 ,,	—	3	—	10 38 14 ,,	—	3	—
10 11 51 ,,	—	2	27	10 38 55 ,,	—	1	—
10 12 27 ,,	—	4	—	10 39 19 ,,	—	1	—
10 12 49 ,,	—	2	—	10 40 39 ,,	—	2	27
10 14 03 ,,	—	2	—	10 41 44 ,,	5.7	3	41
10 14 30 ,,	—	3	—	10 43 01 ,,	—	3	—
10 15 35 ,,	—	2	—	10 43 19 ,,	—	2	—
10 16 46 ,,	—	2	—	10 43 40 ,,	—	3	31
10 17 14 ,,	—	2	—	10 44 44 ,,	—	2	36
10 17 53 ,,	—	1	—	10 47 07 ,,	—	2	—
10 18 07 ,,	—	1	—	10 48 16 ,,	—	2	—
10 18 49 ,,	—	2	—	10 50 16 ,,	5.5	2	28
10 19 44 ,,	—	2	—	10 50 51 ,,	—	3	—
10 20 33 ,,	4.5	3	—	10 51 28 ,,	—	3	—
10 21 07 ,,	—	2	—	10 51 47 ,,	—	2	—
10 21 34 ,,	—	2	—	10 52 19 ,,	—	1	—
10 22 13 ,,	—	2	—	10 53 22 ,,	—	1	—
10 22 50 ,,	—	2	—	10 54 01 ,,	—	2	—
10 23 32 ,,	—	1	—	10 54 34 ,,	—	2	—
10 23 57 ,,	—	2	—	10 55 34 ,,	—	2	—
10 24 23 ,,	—	3	—	10 56 37 ,,	—	2	—
10 25 11 ,,	—	3	—	10 57 27 ,,	—	3	—
10 25 51 ,,	—	2	—	10 58 27 ,,	—	2	—
10 26 39 ,,	—	3	—	10 59 49 ,,	—	2	—
10 27 04 ,,	—	3	34	11 00 33 ,,	—	1	—
10 28 12 ,,	—	3	—	11 01 15 ,,	—	1	—
10 28 33 ,,	—	2	36	11 02 04 ,,	—	2	—
10 29 27 ,,	—	1	—	11 03 35 ,,	—	2	—
10 30 00 ,,	—	3	34	11 04 38 ,,	—	2	—
10 30 51 ,,	—	2	—	11 05 07 ,,	—	1	—
10 31 13 ,,	—	2	—	11 05 31 ,,	—	2	—
10 31 44 ,,	—	2	—	11 06 08 ,,	—	2	—
10 32 48 ,,	—	2	—	11 06 36 ,,	—	1	—
10 33 44 ,,	—	2	—	11 07 31 ,,	—	1	—
10 34 00 ,,	—	2	—	11 08 07 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
OCT. 15	sec.	μ	sec.	OCT. 15	sec.	μ	sec.
11 08 21 a.m.	—	1	—	11 46 32 a.m.	—	1	—
11 09 40 ,,	5.3	3	—	11 47 24 ,,	—	4	51
11 10 14 ,,	—	1	—	11 48 51 ,,	—	1	—
11 10 52 ,,	—	1	—	11 49 09 ,,	—	1	—
11 11 34 ,,	—	1	—	11 49 25 ,,	—	2	—
11 11 50 ,,	—	1	—	11 50 13 ,,	—	1	—
11 12 47 ,,	—	1	—	11 51 10 ,,	—	2	—
11 13 16 ,,	—	1	—	11 52 50 ,,	—	1	—
11 15 51 ,,	—	2	—	11 53 38 ,,	—	1	—
11 16 40 ,,	—	2	—	11 54 28 ,,	—	2	—
11 18 33 ,,	—	2	—	11 55 39 ,,	—	1	—
11 18 41 ,,	—	2	—	11 56 26 ,,	—	2	—
11 20 08 ,,	—	2	—	11 56 54 ,,	—	1	—
11 20 41 ,,	—	1	—	11 57 23 ,,	—	1	—
11 21 17 ,,	—	3	27	11 58 01 ,,	—	2	—
11 21 58 ,,	—	2	—	11 58 36 ,,	—	3	—
11 23 02 ,,	—	1	—	11 59 03 ,,	—	2	—
11 23 44 ,,	—	2	—	11 59 33 ,,	—	2	—
11 24 12 ,,	—	1	—	0 00 06 p.m.	—	2	—
11 24 53 ,,	—	2	—	0 00 32 ,,	—	1	—
11 25 32 ,,	—	1	—	0 01 04 ,,	—	1	—
11 26 19 ,,	—	1	—	0 01 51 ,,	—	3	—
11 27 36 ,,	—	1	—	0 02 49 ,,	—	2	—
11 30 32 ,,	—	1	—	0 03 25 ,,	—	2	—
11 30 58 ,,	—	1	—	0 04 16 ,,	—	1	—
11 32 58 ,,	—	1	—	0 05 05 ,,	—	2	—
11 34 10 ,,	—	1	—	0 05 47 ,,	—	1	—
11 34 52 ,,	—	2	—	0 06 14 ,,	—	1	—
11 36 34 ,,	—	1	—	0 07 15 ,,	—	3	—
11 38 14 ,,	—	3	42	0 07 43 ,,	—	3	—
11 39 15 ,,	—	1	—	0 08 31 ,,	—	2	—
11 39 47 ,,	—	1	—	0 09 23 ,,	—	2	—
11 40 13 ,,	—	1	—	0 09 39 ,,	—	3	—
11 40 54 ,,	—	1	—	0 10 09 ,,	—	2	—
11 42 07 ,,	—	1	—	0 10 47 ,,	—	2	—
11 42 43 ,,	—	2	—	0 11 08 ,,	—	2	—
11 43 16 ,,	—	2	—	0 11 43 ,,	—	2	—
11 43 44 ,,	—	1	—	0 12 45 ,,	—	2	—
11 44 36 ,,	—	1	—	0 13 31 ,,	—	2	—
11 45 45 ,,	—	2	45	0 14 28 ,,	—	3	—

Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.	Date (1913) and Time of Occurrence.	Duration of Preliminary Tremor.	2a.	Total Duration.
OCT. 15	sec.	μ	sec.	**OCT. 15**	sec.	μ	sec.
0 15 01 p.m.	—	2	—	0 42 38 p.m.	—	1	—
0 15 19 ,,	—	2	—	0 43 27 ,,	—	2	—
0 16 12 ,,	—	2	—	0 44 23 ,,	—	2	—
0 16 49 ,,	—	3	—	0 45 41 ,,	—	2	—
0 17 52 ,,	—	3	—	0 49 37 ,,	—	1	—
0 18 21 ,,	—	2	—	0 53 33 ,,	—	1	—
0 19 09 ,,	—	3	—	0 54 51 ,,	—	1	—
0 19 26 ,,	—	3	—	0 56 52 ,,	—	1	—
0 20 27 ,,	—	2	—	0 57 33 ,,	—	1	—
0 21 18 ,,	—	1	—	0 57 50 ,,	—	1	—
0 21 53 ,,	—	2	—	0 58 14 ,,	—	2	20
0 22 17 ,,	—	1	—	1 02 34 ,,	—	1	—
0 23 21 ,,	—	1	—	1 03 53 ,,	—	1	—
0 23 56 ,,	—	1	—	1 05 11 ,,	—	2	—
0 24 27 ,,	—	4	34	1 05 42 ,,	—	2	—
0 25 20 ,,	—	2	—	1 06 08 ,,	—	1	—
0 25 59 ,,	—	1	—	1 06 22 ,,	—	2	—
0 26 11 ,,	—	1	—	1 06 56 ,,	—	1	—
0 26 50 ,,	—	2	—	1 07 44 ,,	—	1	—
0 28 19 ,,	—	1	—	1 08 14 ,,	—	2	—
0 28 51 ,,	—	2	—	1 16 53 ,,	—	1	—
0 29 39 ,,	—	1	—	1 17 40 ,,	—	1	—
0 30 46 ,,	—	1	—	1 17 52 ,,	—	2	35
0 31 21 ,,	—	3	—	1 20 57 ,,	—	2	28
0 31 49 ,,	—	2	—	1 21 44 ,,	—	2	—
0 32 37 ,,	—	2	—	1 22 08 ,,	—	1	37
0 33 26 ,,	—	1	—	1 23 20 ,,	—	2	26
0 34 48 ,,	—	1	—	1 25 30 ,,	—	2	24
0 35 29 ,,	—	2	—	1 26 34 ,,	—	1	24
0 36 11 ,,	—	2	—	1 29 36 ,,	—	1	—
0 36 50 ,,	—	1	—	1 31 19 ,,	—	1	—
0 37 20 ,,	—	4	—	1 34 49 ,,	—	1	—
0 37 45 ,,	—	1	—	1 35 55 ,,	—	1	—
0 39 44 ,,	—	2	25	1 38 13 ,,	—	1	—
0 42 05 ,,	—	1	—	1 38 30 ,,	—	1	—

Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.	Date (1913) and Time of Occurrence.	Duration of Prelimi-nary Tremor.	2a.	Total Dura-tion.
OCT. 15	sec.	μ	sec.	**OCT. 18**	sec.	μ	sec.
1 45 24 p.m.	—	3	28	4 40 58 a.m.	—	3	19
6 26 56 ,,	—	2	18				
10 43 13 ,, (1)	0.5	35	94	**OCT. 20**			
				10 44 31 a.m.(4)	—	3	33
OCT. 16							
1 39 08 a.m.(2)	—	4	35	**OCT. 22**			
				3 55 42 a.m.(5)	1.0	28	104
OCT. 17							
3 27 47 p.m.(3)	—	66	116				

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(1): strong explosion; the transverse max. 2a=21μ.
(2): the transverse max. 2a.=3μ.
(3): ,, ,, 38μ.
(4): ,, 3μ.
(5): ,, ,, 21μ.

On Oct. 18th, at 0.24.18 a.m., there was an unfelt earthquake shock, of the following elements of motion: dur. prel. tremor=0 sec.; max. longitudinal 2a=4μ; total duration=5 sec.

TABLE II. LIST OF THE ASAMA VOLCANIC DISTURBANCES INSTRUMENTALLY REGISTERED AT THE ASAMA-YAMA (YUNO-TAIRA) SEISMOLOGICAL OBSERVATORY. MAY 1ST TO OCT. 31ST, 1914.

[A]....VOLCANIC EARTHQUAKE NOT ACCOMPANIED BY ERUPTION.
[B]....EARTH SHAKING CAUSED BY VOLCANIC ERUPTION.

(2a denotes the maximum range of motion, in micron.)

Date (1914).	Time of Occurrence.	Duration of Preliminary Tremor.	Max. 2a. Longitudinal.	Max. 2a. Transverse.	Total Duration.	Remark.
		sec.	μ	μ	sec.	
MAY 5	0 24 51 a.m.	—	2	—	12	B
"	0 31 52 "	—	1	—	13	"
"	0 33 03 "	0.55	176	192	171	B (Strong explosion.)
"	0 38 55 "	—	2	—	13	B
"	1 10 53 "	—	1	—	16	"
14	2 17 14 "	—	1	—	16	"
"	5 08 57 "	—	1	—	17	"
15	8 58 16 "	0.5	10	14	43	A
18	7 10 44 "	0.5	22	20	7	"
19	6 05 55 "	0.0	12	6	3	"
24	0 21 58 "	0.7	67	70	25	"
"	0 22 31 "	0.7	59	56	20	"
JUNE 7	6 00 12 "	0.25	47	38	16	"
14	8 01 35 p.m.	0.0	14	16	—	"
15	7 00 05 a.m.	0.8	26	20	53	A, sensible.
20	9 55 53 p.m.	1.4	11	3	17	A
21	8 26 51 a.m.	1.8	22	17	34	B
"	8 35 36 "	1.7	19	14	33	"
"	0 34 34 p.m.	1.5	3	2	18	"
"	0 51 33 "	1.4	2	2	20	"
"	5 41 50 "	1.0	5	2	16	"
"	6 16 12 "	1.8	6	3	25	"
"	6 56 53 "	—	3	3	21	"
"	6 58 35 "	0.9	3	3	21	"
"	7 00 55 "	1.8	4	2	20	"
"	7 01 55 "	1.5	3	—	15	"
"	7 02 16 "	—	1	—	18	"
"	7 03 34 "	—	1	1	20	"
23	4 26 01 "	0.8	10	6	34	A
25	2 29 18 "	0.75	81	48	23	A, sensible.

Date (1914).	Time of Occurrence.	Duration of Preliminary Tremor.	Max. 2a.		Total Duration.	Remark.
			Longitudinal.	Transverse.		
		sec.	μ	μ	sec.	
JUNE 29	4 53 18 p.m.	0.7	19	10	11	A.
JULY 6	2 34 13 „	0.0	15	8	6	„
„	2 34 20 „	0.0	5	4	3	„
10	4 56 59 a.m.	0.8	19	14	25	„
11	3 24 54 „	0.5	34	22	10	„
14	2 21 09 „	0.6	22	26	26	„ Sensible; accompanied with a sound like that caused by the falling of a heavy body on the ground.
„	9 43 30 p.m.	0.4	68	76	40	A
17	7 28 31 „	0.9	18	—	7	A
25	0 21 24 a.m.	—	2	2	11	B
AUG. 6	8 54 10 p.m.	0.35	2	1	5	A
„	8 54 18 „	0.35	22	12	13	„
12	9 48 30 a.m.	1.0	40	25	26	„
20	2 45 03 p.m.	0.0	16	5	5	„
25	11 12 57 „	0.24	27	24	—	„
„	11 13 00 „	—	9	10	—	„
26	2 22 32 a.m.	0.0	24	10	8	„
„	6 45 46 „	0.3	15	—	6	„
28	0 28 34 p.m.	0.0	24	—	6	„
29	4 05 26 a.m.	0.56	40	—	11	„
„	4 11 40 „	0.65	30	5	9	„
SEPT. 7	1 15 50 „	—	2	—	22	B
13	3 04 46 p.m.	0.3	77	90	24	A, sensible.
16	9 37 40 „	0.3	50	35	15	„ „
20	9 59 39 „	0.5	8	5	24	B
21	6 42 14 a.m.	0.3	11	—	3	A
„	0 43 10 p.m.	0.0	9	—	3	„
„	0 43 57 „	0.0	15	—	4	„
22	1 05 44 „	—	12	—	4	„
„	9 52 01 „	0.4	49	—	13	A, sensible.
29	11 39 10 „	0.5	7	—	4	A
OCT. 1	3 04 57 „	0.0	29	—	6	„
8	3 21 35 a.m.	0.6	50	—	15	A, sensible.
„	3 38 31 „	0.5	60	—	16	„ „
„	3 41 27 „	0.5	35	—	16	„ „
„	5 24 13 p.m.	1.2	14	—	25	B
14	7 37 28 a.m.	0.0	37	—	5	A
„	8 02 25 „	0.0	20	—	10	„
16	7 30 40 „	0.0	25	—	25	„
„	8 40 07 p.m.	0.0	15	—	15	„
22	0 41 44 a.m.	1.8	5	3	23	B

Date (1914).	Time of Occurrence.	Duration of Preliminary Tremor.	Max. 2a.		Total Duration.	Remark.
			Longitudinal.	Transverse.		
		sec.	μ	μ	sec.	
OCT. 26	8 36 06 p.m.	0.57	70	47	20	A, sensible.
29	5 03 25 a.m.	0.4	3	3	21	B
,,	7 39 04 ,,	0.9	2	2	20	,,
,,	7 46 41 p.m.	0.7	27	28	26	A, sensible.
31	11 27 22 a.m.	1.3	4	—	26	B
,,	11 27 53 ,,	—	1	—	20	,,
,,	11 28 48 ,,	0.9	4	—	37	,,
,,	11 31 15 ,,	—	2	—	18	,,
,,	11 46 53 ,,	0.8	2	—	22	,,

TABLE III. LIST OF THE ASAMA VOLCANIC DISTURBANCES INSTRUMENTALLY REGISTERED AT THE ASAMA-YAMA (YUNO-TAIRA) SEISMOLOGICAL OBSERVATORY.

MAY 1ST TO OCT. 31ST, 1915.

[A]....VOLCANIC EARTHQUAKE NOT ACCOMPANIED BY ERUPTION.
[B]....EARTH SHAKING CAUSED BY VOLCANIC ERUPTION.

(2a denotes the maximum range of motion, in micron.)

Each of the disturbances marked with an asterisc (*) was an earthquake of origin situated, not directly under, but at some short distance from, the volcano.

Date (1915).	Time of Occurrence.	Duration of Preliminary Tremor.	Max. 2a.		Total Duration.	Remark.
			Longitudinal.	Transverse.		
		sec.	μ	μ	sec.	
MAY 3	2 56 45 p.m.	0.6	67	55	—	A, sensible.
4	1 13 50 a.m.	1.2	3	2	23	*
10	10 59 42 p.m.	0.45	13	8	29	A
11	8 40 59 a.m.	0.45	28	—	31	,,
,,	9 00 26 ,,	0.4	38	—	34	,,
,,	3 23 25 p.m.	0.4	35	—	27	,,
15	10 08 40 ,,	0.4	19	6	11	,,
17	8 34 35 a.m.	—	6	3	16	*
22	5 45 39 ,,	—	2	—	18	*
,,	4 51 34 p.m.	0.0	4	—	4	A
27	5 17 26 a.m.	0.0	28	—	10	,,
29	6 30 55 p.m.	0.45	53	—	25	,,
JUNE 3	9 42 37 a.m.	0.0	37	—	30	,,
,,	9 53 58 ,,	—	13	—	10	,,
,,	10 04 06 ,,	—	11	—	4	,,
4	8 28 50 p.m.	—	4	—	5	,,
,,	8 29 15 ,,	0.3	112	82	45	A, sensible.
6	4 11 31 ,,	0.34	43	29	24	,, ,,
13	4 29 34 ,,	0.0	24	19	5	A
16	10 44 29 a.m.	0.2	152	70	43	A, sensible.
,,	11 09 13 ,,	0.2	13	—	16	,, ,,
,,	1 42 56 p.m.	0.3	19	—	11	,, ,,
18	5 01 23 ,,	0.5	67	38	25	,, ,,
20	8 07 21 a.m.	0.8	43	37	35	A
24	8 15 42 ,,	0.47	38	—	19	,,
,,	0 27 22 p.m.	0.58	40	43	21	A, sensible.
30	7 51 01 ,,	0.43	73	50	9	,, ,,
,,	7 51 15 ,,	—	9	—	8	A
JULY 1	5 02 37 ,,	0.4	24	—	10	,,
4	5 47 48 ,,	—	18	13	25	,,

Date (1915).	Time of Occurrence.	Duration of Preliminary Tremor.	Max. 2a.		Total Duration.	Remark.
			Longitudinal.	Transverse.		
		sec.	μ	μ	sec.	
JULY 7	0 20 28 a.m.	0.38	71	—	23	A, sensible.
9	2 47 01 ,,	—	58	57	—	,, ,,
,,	2 47 07 ,,	—	38	35	—	A
,,	2 47 13 ,,	—	12	—	—	,,
,,	2 49 36 ,,	—	17	—	9	,,
,,	10 28 13 p.m.	0.4	16	10	9	,,
14	1 25 40 a.m.	0.35	47	48	23	A, sensible.
,,	7 46 38 ,,	0.4	38	35	33	,, ,,
,,	11 11 50 ,,	0.53	138	106	90	,, ,,
15	11 30 16 ,,	0.5	33	30	13	,, ,,
16	0 16 31 p.m.	0.55	7	—	10	A
17	1 49 34 a.m.	1.9	25	—	44	*
,,	10 41 14 p.m.	0.5	16	—	7	A
18	9 15 54 a.m.	0.3	43	—	—	,,
,,	9 16 07 ,,	0.0	50	—	21	A, sensible.
,,	8 04 29 p.m.	0.86	81	100	72	,, ,,
19	1 17 05 a.m.	0.3	29	—	21	,, ,,
24	10 31 46 ,,	—	7	—	6	A
29	11 29 29 p.m.	0.8	9	—	8	,,
AUG. 6	3 55 44 a.m.	0.0	45	—	15	A, sensible.
7	5 32 34 ,,	0.28	48	—	11	,, ,,
9	2 47 16 ,,	0.6	49	—	26	,, ,,
19	5 33 49 ,,	0.9	41	—	13	,, ,,
,,	9 40 49 p.m.	0.6	2	—	5	A
,,	11 57 38 ,,	0.5	4	—	24	,,
21	5 43 01 ,,	0.5	60	—	—	A, sensible.
,,	5 43 23 ,,	—	17	—	9	A
24	8 54 44 ,,	0.5	56	46	65	A, sensible.
25	8 52 50 ,,	1.4	4	1	24	*
26	9 03 48 a.m.	0.7	4	5	27	*
28	9 35 08 p.m.	—	2	2	21	*
31	7 42 15 ,,	0.53	75	60	30	A, sensible.
,,	10 47 05 ,,	—	2	—	—	*
SEPT. 1	11 23 53 ,,	0.6	128	63	40	A, sensible.
,,	11 56 25 ,,	0.4	44	38	25	,, ,,
2	2 42 41 ,,	0.5	122	78	—	,, ,,
,,	2 42 59 ,,	—	13	—	—	A
,,	2 43 02 ,,	—	47	29	—	A, sensible.
,,	2 43 05 ,,	—	29	27	—	,, ,,
,,	2 43 29 ,,	—	13	13	—	A

Date (1915).	Time of Occurrence.	Duration of Prelimi-nary Tremor.	Max. 2a.		Total Dura-tion.	Remark.
			Longi-tudinal.	Trans-verse.		
		sec.	μ	μ	sec.	
SEPT. 2	2 43 35 p.m.	—	59	23	—	A, sensible.
„	2 43 37 „	—	22	20	—	A
„	2 44 10 „	0.5	33	—	13	A, sensible.
5	7 27 25 a.m.	0.3	29	—	21	A
„	10 50 25 p.m.	0.5	555	990	285	A, sensible.
7	10 53 20 „	0.7	8	5	10	A
11	3 21 21 a.m.	0.4	10	10	19	„
„	3 22 32 „	0.3	72	62	39	A, sensible.
„	3 23 22 „	0.3	3	1	—	A
„	3 23 29 „	—	53	—	28	„
17	11 04 08 p.m.	1.6	10	4	30	*
„	11 05 00 „	1.3	9	3	35	*
18	9 00 26 a.m.	0.6	31	27	—	A
„	9 00 32 „	—	154	100	90	A, sensible.
19	9 25 28 „	0.45	239	145	—	„ „
„	9 25 45 „	—	18	7	—	A
„	9 25 52 „	—	133	65	—	A, sensible.
„	9 26 24 „	0.6	136	58	25	„ „
„	10 58 44 „	0.75	6	5	17	A
„	11 04 27 „	1.2	3	1	18	*
„	11 25 40 „	0.65	28	25	14	A
20	0 59 00 p.m.	0.52	39	—	20	A, sensible.
OCT. 2	0 42 01 „	0.56	5	2	11	A
4	5 06 50 a.m.	0.7	7	—	15	„
„	0 32 58 p.m.	0.6	14	5	20	„
9	10 57 06 „	0.55	71	52	22	A, sensible.
10	10 48 30 „	0.0	40	—	35	A
„	11 44 29 „	0.0	365	—	120	A, sensible.
12	2 56 37 „	1.5	10	—	18	*
18	9 04 52 a.m.	0.5	57	—	18	A
„	2 43 40 p.m.	0.0	125	—	22	A, sensible.
„	2 47 31 „	0.0	25	—	9	A
23	6 32 50 „	0.35	15	6	8	„
„	6 33 17 „	0.35	113	77	28	A, sensible.
25	4 23 11 a.m.	1.7	51	47	68	Sensible *
„	10 26 11 „	0.0	9	—	10	A
„	7 45 25 p.m.	1.2	22	—	35	*
26	4 53 21 „	0.48	75	—	13	A
29	4 46 53 a.m.	1.2	20	18	35	*

TABLE IV. LIST OF THE ASAMA VOLCANIC DISTURBANCES INSTRUMENTALLY REGISTERED AT THE ASAMA-YAMA (YUNO-TAIRA) SEISMOLOGICAL OBSERVATORY. MAY 1ST TO NOV. 1ST, 1916.

[A]....VOLCANIC EARTHQUAKE NOT ACCOMPANIED BY ERUPTION.
[B]....EARTH SHAKING CAUSED BY VOLCANIC ERUPTION.

(2a denotes the maximum range of motion, in micron.)

Each of the disturbances marked with an asterisc (*) was an earthquake of origin situated, not directly under, but at some short distance from, the volcano.

Date (1916).	Time of Occurrence.	Duration of Prelimi-nary Tremor.	Max. 2a.		Total Dura-tion.	Remark.
			Longi-tudinal.	Trans-verse.		
		sec.	μ	μ	sec.	
MAY 4	0 47 19 a.m.	0.0	18	—	13	A
8	9 53 08 ,,	0.5	167	168	53	A, sensible.
16	4 03 23 ,,	0.5	15	5	10	A
,,	4 03 34 ,,	0.0	15	15	10	,,
,,	4 08 42 ,,	0.3	23	—	5	,,
18	10 15 48 ,,	1.4	18	—	60	*
20	0 49 18 p.m.	0.2	25	—	12	A
23	5 03 37 ,,	0.3	6	—	12	,,
25	7 22 58 ,,	0.0	33	—	11	,,
26	6 07 18 a.m.	0.4	67	35	25	A, sensible.
,,	6 42 42 ,,	0.25	15	—	4	A
29	11 47 40 p.m.	0.5	8	—	15	,,
30	5 15 49 a.m.	1.3	10	—	27	*
,,	11 14 43 p.m.	1.2	17	—	34	*
JUNE 5	9 05 53 ,,	0.5	23	13	20	A, sensible.
20	11 45 33 a.m.	0.5	28	13	13	A
22	10 56 47 ,,	0.5	25	7	7	,,
24	7 36 49 ,,	—	37	—	28	,,
,,	8 53 25 ,,	—	7	—	6	,,
JULY 4	0 22 19 p.m.	0.57	75	92	68	A, sensible.
,,	0 23 55 ,,	0.33	133	86	74	,, ,,
10	3 57 28 a.m.	1.3	8	8	—	*
,,	3 57 42 ,,	—	4	4	40	*
13	10 23 28 p.m.	0.2	17	6	4	A
15	8 52 30 ,,	0.6	173	145	—	A, sensible.
,,	8 52 38 ,,	—	293	142	—	,, ,,
,,	8 53 09 ,,	0.7	35	17	—	A
20	8 36 49 a.m.	1.2	28	23	67	Sensible *
21	10 56 01 p.m.	1.3	39	43	55	Sensible *
26	6 15 02 ,,	0.4	8	7	20	A

Date (1916).	Time of Occurrence.	Duration of Preliminary Tremor.	Max. 2a.		Total Duration.	Remark.
			Longitudinal.	Transverse.		
		sec.	μ	μ	sec.	
JULY 27	1 15 00 a.m.	—	2	1	6	A
,,	1 15 20 ,,	0.5	21	20	—	A, sensible.
,,	1 15 22 ,,	—	23	25	—	,, ,,
,,	1 15 27 ,,	—	9	8	—	A
,,	1 15 29 ,,	—	155	120	85	A, sensible.
,,	2 10 17 ,,	—	1	2	—	A
,,	2 10 28 ,,	—	2	3	—	,,
,,	2 10 33 ,,	—	8	7	9	,,
,,	9 54 49 p.m.	0.9	6	—	14	,,
28	2 31 12 ,,	—	5	—	4	,,
AUG. 2	5 27 07 p.m.	0.6	43	25	—	,,
,,	5 27 10 ,,	—	25	12	20	,,
3	1 46 08 ,,	0.6	12	10	10	,,
5	3 30 03 a.m.	0.5	14	10	10	,,
10	2 50 27 p.m.	0.8	15	10	18	*
15	5 51 10 a.m.	0.4	60	50	} 6	A, sensible.
,,	5 51 13 ,,	—	7	10		A
,,	7 43 28 ,,	0.8	130	130	80	A, sensible.
,,	7 55 10 ,,	0.6	130	65	90	,, ,,
,,	8 45 35 p.m.	0.6	50	72	80	,, ,,
17	3 17 23 ,,	0.5	150	90	20	,, ,,
,,	3 19 03 ,,	0.3	38	30	4	A
,,	8 36 54 ,,	0.5	22	45	13	,,
21	1 44 19 ,,	0.7	8	8	8	,,
24	10 19 24 a.m.	1.2	5	3	18	*
25	10 18 34 ,,	0.5	10	—	8	A
30	0 08 10 p.m.	0.5	13	10	7	,,
,,	7 50 43 ,,	0.6	60	50	10	A, sensible.
31	0 28 48 a.m.	0.0	16	17	—	A
,,	0 28 50 ,,	0.0	10	—	—	,,
,,	0 28 51 ,,	—	13	8	—	,,
,,	0 28 55 ,,	0.5	68	45	—	A, sensible.
,,	0 28 59 ,,	0.5	41	47	—	,, ,,
,,	0 29 04 ,,	—	159	133	28	,, ,,
,,	0 29 32 ,,	0.5	26	14	10	A
SEPT. 1	10 55 58 ,,	0.3	5	5	6	,,
,,	11 20 10 ,,	0.5	10	14	11	,,
,,	11 21 18 ,,	0.4	35	28	42	A, sensible.
,,	0 25 35 p.m.	0.2	11	11	12	A
,,	0 45 39 ,,	0.2	9	13	8	,,

Date (1916).	Time of Occurrence.	Duration of Preliminary Tremor.	Max. 2a.		Total Duration.	Remark.
			Longitudinal.	Transverse.		
		sec.	μ	μ	sec.	
SEPT. 1	0 45 55 p.m.	0.4	7	3	8	A
„	8 01 22 „	0.6	82	82	54	A, sensible.
„	9 48 56 „	0.5	37	30	35	„ „
„	10 34 24 „	0.4	6	5	6	A
3	6 23 49 a.m.	—	6	—	7	„
„	11 20 08 „	0.8	11	—	13	„
4	3 02 14 p.m.	—	2	2	6	„
„	3 02 27 „	—	3	2	6	„
„	3 03 09 „	0.6	37	25	16	A, sensible.
„	3 05 23 „	0.5	88	68	53	„ „
„	5 38 39 „	—	4	3	7	A
„	5 41 54 „	0.4	7	6	9	„
„	5 42 03 „	—	4	2	6	„
„	5 42 41 „	—	7	3	10	„
„	5 43 12 „	—	19	16	10	„
„	5 44 05 „	—	7	5	6	„
„	5 44 11 „	0.4	7	3	6	„
„	5 44 23 „	0.4	213	135	—	A, sensible.
„	5 44 59 „	0.0	39	24	23	A
„	5 46 26 „	—	3	1	10	„
„	5 46 51 „	0.3	6	2	5	„
„	5 46 57 „	0.3	75	75	14	A, sensible.
„	5 47 11 „	—	7	4	9	A
„	7 27 52 „	0.6	25	11	10	„
„	7 28 47 „	0.5	31	21	17	A, sensible.
„	7 29 04 „	0.3	51	38	12	„ „
„	7 33 04 „	—	7	2	6	A
„	9 13 26 „	0.3	6	2	5	„
„	10 11 50 „	0.5	37	26	41	A, sensible.
„	10 13 41 „	0.7	51	34	42	„ „
6	1 23 38 „	0.5	12	5	6	A
„	1 24 20 „	0.4	135	108	28	A, sensible.
„	1 27 30 „	0.3	39	42	10	„ „
8	4 52 11 „	0.7	20	24	12	A
„	4 52 29 „	0.6	23	15	30	„
9	1 43 26 „	0.6	12	12	12	„
13	5 18 46 a.m.	0.7	70	85	37	A, sensible.
„	3 24 38 p.m.	1.3	52	34	29	Sensible *
14	9 37 36 a.m.	0.4	19	—	10	A
15	9 56 43 p.m.	0.7	54	32	78	A, sensible.

Date (1916).	Time of Occurrence.	Duration of Preliminary Tremor.	Max. 2a.		Total Duration.	Remark.
			Longitudinal.	Transverse.		
		sec.	μ	μ	sec.	
SEPT. 17	6 20 47 p.m.	0.6	65	53	23	A, sensible.
21	3 06 40 ,,	1.3	56	47	114	Sensible *
,,	4 27 48 ,,	1.3	40	29	} 107	Sensible *
,,	4 28 26 ,,	—	8	6		*
22	1 21 46 ,,	—	22	13	18	A
25	2 44 52 a.m.	1.3	13	31	34	*
,,	3 37 28 ,,	1.3	15	14	39	*
26	6 31 23 p.m.	0.5	4	—	8	A
27	2 35 16 a.m.	0.7	63	57	28	A, sensible.
28	9 59 06 p.m.	—	7	7	6	A
OCT. 1	5 07 31 p.m.	—	9	3	14	,,
2	6 56 26 a.m.	—	2	2	73	B
,,	10 18 24 ,,	—	6	2	6	A
,,	1 55 29 p.m.	—	1	1	44	B
,,	10 53 27 ,,	0.6	6	3	6	A
4	3 49 16 ,,	0.0	17	—	14	,,
5	6 20 01 a.m.	0.8	44	38	12	A, sensible.
,,	6 20 13 ,,	0.65	40	36	15	,, ,,
,,	6 20 28 ,,	—	7	7	—	A
,,	6 20 58 ,,	—	2	2	—	,,
,,	6 21 12 ,,	—	2	3	—	,,
,,	6 21 33 ,,	0.65	44	50	33	A, sensible.
,,	6 22 06 ,,	—	2	—	—	A
,,	6 22 43 ,,	—	3	2	—	,,
,,	6 22 58 ,,	—	5	4	—	,,
,,	6 23 30 ,,	—	2	1	—	,,
,,	6 24 27 ,,	0.7	13	18	—	,,
,,	6 24 50 ,,	—	5	4	—	,,
,,	6 25 04 ,,	—	2	1	—	,,
,,	6 25 57 ,,	0.75	13	13	—	,,
,,	6 26 07 ,,	—	995	—	—	A, strongly sensible.
,,	6 26 48 ,,	—	18	—	—	A
,,	6 27 50 ,,	—	26	—	—	A, sensible.
,,	6 27 57 ,,	—	6	—	—	,, ,,
,,	6 28 21 ,,	—	27	—	—	,, ,,
,,	6 28 44 ,,	—	6	—	—	A
,,	6 29 29 ,,	—	3	3	—	,,
,,	6 30 03 ,,	—	5	13	—	,,
,,	6 30 12 ,,	—	7	8	—	,,
,,	6 30 24 ,,	0.7	40	47	35	A, sensible.

Date (1916).	Time of Occurrence.	Duration of Preliminary Tremor.	Max. 2a.		Total Duration.	Remark.
			Longitudinal.	Transverse.		
		sec.	μ	μ	sec.	
OCT. 5	6 31 03 a.m.	—	16	17	—	A
,,	6 31 08 ,,	—	6	5	—	,,
,,	6 31 22 ,,	—	3	2	—	,,
,,	6 32 00 ,,	—	2	—	—	,,
,,	6 32 11 ,,	—	6	4	—	,,
,,	6 32 32 ,,	—	3	2	—	,,
,,	6 32 54 ,,	—	5	3	—	,,
,,	6 33 32 ,,	0.7	23	20	37	A, sensible.
,,	6 34 32 ,,	0.5	423	402	—	,, ,,
,,	6 35 13 ,,	—	14	12	—	A
,,	6 35 50 ,,	—	11	19	—	,,
,,	6 36 06 ,,	—	38	43	—	A, sensible.
,,	6 36 21 ,,	—	14	15	—	A
,,	6 37 07 ,,	—	9	8	—	,,
,,	6 37 49 ,,	—	3	2	—	,,
,,	6 38 35 ,,	—	6	4	—	,,
,,	6 38 45 ,,	—	5	10	—	,,
,,	6 38 48 ,,	—	60	58	—	A, sensible.
,,	6 39 03 ,,	—	24	19	—	A
,,	6 40 10 ,,	—	22	18	—	,,
,,	6 41 08 ,,	—	6	4	—	,,
,,	6 42 01 ,,	—	5	3	—	,,
,,	6 43 08 ,,	—	5	5	—	,,
,,	6 43 57 ,,	—	3	2	—	,,
,,	6 44 17 ,,	—	7	8	—	,,
,,	6 45 13 ,,	—	5	2	—	,,
,,	6 46 34 ,,	—	3	2	—	,,
,,	6 47 49 ,,	—	10	3	—	,,
,,	6 48 19 ,,	0.8	25	23	—	A, sensible.
,,	6 48 55 ,,	—	2	2	13	A
,,	6 51 29 ,,	0.7	325	—	91	A, strongly sensible.
,,	6 53 00 ,,	0.6	114	—	99	,, sensible.
,,	6 55 16 ,,	—	2	—	13	A
,,	6 55 33 ,,	—	4	2	17	,,
,,	6 58 18 ,,	—	6	7	31	,,
,,	7 08 24 ,,	0.7	45	43	38	A, sensible.
,,	7 09 48 ,,	—	5	2	21	A
,,	7 10 20 ,,	—	3	2	15	,,
,,	7 10 35 ,,	—	6	6	13	,,
,,	7 10 48 ,,	—	6	6	20	,,

Date (1916).	Time of Occurrence.	Duration of Preliminary Tremor.	Max. 2a.		Total Duration.	Remark.
			Longitudinal.	Transverse.		
		sec.	μ	μ	sec.	
OCT. 5	7 11 31 a.m.	—	4	2	13	A
"	7 12 59 "	—	3	2	12	"
"	7 13 55 "	—	4	3	12	"
"	7 21 41 "	—	3	2	—	"
"	7 36 48 "	—	8	3	22	"
"	7 39 00 "	0.7	24	15	22	A, sensible.
"	7 41 14 "	—	3	3	12	A
"	8 04 20 "	—	4	3	20	"
"	8 15 55 "	—	6	6	8	"
"	8 48 19 "	—	3	2	15	"
"	8 51 35 "	0.5	50	24	26	"
"	9 09 08 "	—	5	3	10	"
"	9 11 45 "	—	4	2	11	"
"	9 15 35 "	—	4	2	11	"
"	9 17 15 "	—	2	2	8	"
"	9 25 36 "	—	3	3	10	"
"	9 25 59 "	—	7	2	13	"
"	9 26 12 "	0.6	201	209	—	A, sensible.
"	9 26 29 "	—	45	28	—	A
"	9 26 46 "	—	95	88	67	A, sensible.
"	10 26 45 "	—	5	2	10	A
"	10 27 07 "	—	4	2	10	"
"	10 40 24 "	—	4	2	12	"
"	11 51 37 "	0.7	61	35	25	A, sensible.
"	1 05 41 p.m.	—	3	2	20	A
"	1 07 29 "	—	3	1	16	"
"	1 35 15 "	—	3	2	—	"
"	2 06 40 "	—	3	2	12	"
"	5 15 52 "	—	12	—	8	"
6	4 36 07 a.m.	0.0	53	33	36	A, sensible.
7	3 11 44 p.m.	0.6	132	84	28	" "
8	0 45 46 "	0.7	20	20	12	A
9	0 52 28 a.m.	0.6	13	8	11	"
11	0 13 56 "	0.5	18	17	5	"
13	3 06 00 "	0.9	15	15	12	*

Date (1916).	Time of Occurrence.	Duration of Preliminary Tremor.	Max. 2a.		Total Duration.	Remark.
			Longitudinal.	Transverse.		
		sec.	μ	μ	sec.	
OCT. 15	7 04 08 a.m.	—	20	16	5	A
16	5 58 22 p.m.	0.0	20	—	—	,,
,,	5 58 25 ,,	—	5	—	—	,,
,,	5 58 33 ,,	—	4	—	—	,,
29	5 37 50 ,,	0.6	55	35	18	A, sensible.
NOV. 1	2 41 55 a.m.	0.4	9	6	7	A

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Vol. VIII. No. 1.

SEPTEMBER 1914.

TOKYO.

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SEPTEMBER 1914.

TOKYO.

The Sakura-Jima Eruptions and Earthquakes. I.

[General Account.*]

By

F. Omori, Sc. D.,

Member of the Imperial Earthquake Investigation Committee.

With Plates I–VII.

1. ***Introduction.*** The Sakura-jima (Cherry Island), situated in the Kagoshima Bay, and famous for the eruptions in 1779 and several earlier years, made outbursts in January, 1914, which may be counted, in point of the magnitude of disturbance, as one of the greatest volcanic catastrophes in modern times, and caused at once a multitude of scientific and other men to hasten from different parts of the Empire to the south-western extremity of the old Nippon. There were also a number of foreign visitors, including such high vulcanological authorities as Prof. T. A. Jagger, Jr., and Mr. Frank A. Perrett. The present author, who was despatched as a member of the Imperial Earthquake Investigation Committee, left Tokyo on Jan. 14th, arrived in Kagoshima on the 16th, and remained in the stricken district till the 26th; having paid a second visit to Kagoshima and the Sakura-jima in April last. The following § § give a short preliminary account, from the seismological point of view, of this Sakura-jima eruption, whose occurrence indicated the existence of a clear sequence among the various manifestations of the recent volcanic activity in Japan.

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* Translation, with additions, of the present author's article on the Sakura-jima eruptions published in the Toyo Gakugei Zasshi, for March 1914.

2. *Topography.* (See Figs. 1 and 2.) The Sakura-jima is in shape an irregular ellipse, with the longer and shorter diameters of about 9.9 and 8.0 km in the EW and NS directions approximately, the greatest extension being the length of 11.4 km between the ESE coasts and the Hakamagoshi. The latter, a square flat-top piece of ground 0.8 km in length and 72 m in height, is so called from the resemblance of its form to a trapezium, or back head of the Japanese pantaloons when seen from the city of Kagoshima, and is the only portion in the island which is sedimentary in formation, all the rest being covered by volcanic materials. Near the centre of the island there are two high peaks, the Minami-dake (south crater) and the Kita-dake (north crater), respectively 1069.6 and 1133.5 metres in height, which form together with the Futanaka, or slightly depressed intermediate portion, the top ridge, 1.8 km in length running nearly in the S–N direction. Thus, from the E or the W side, the island looks like a truncated triangle and presents a beautiful Fuji type outline with a flat top; while, from the N or the S side, it appears in the form of a pointed cone. On the SE part of the island there is a flat ring-shaped parasitic cone of the Nabe-yama (height=328.4m), opening eastwards and having the maximum base diameter of about 1.5 km. Among the side craters on the west, the most conspicuous is the dome of Hikinohira (height=553 m). Again, the rocky protuberances of the Moe-zaki ("Burning promontary"), the Tatsu-zaki (" Dragon promontary "), and Omoe-zaki (" Great burning promontary "), respectively on the SW, the S, and the NE side of the island were formed by the lava streams attending the eruptions in the historical times. Further, the isle of Moe-jima ("Burning island") and other smaller ones situated off the NE coast of the Sakura-jima are the results of the submarine outbursts, which followed the great eruption in the 8th year of the Anei period (1779 A. C.), and are collectively known as the "Anei Islands". The small iles of Karasu-jima and Oko-jima, respectively off the W. coast of the Sakura-jima and off the Moe-zaki at its SW corner, are also evidently the results of some of the former eruptions. Finally, as a special geographical feature of the island is to be mentioned the existence of hot springs at Furusato, Yunohama, Arimura, and Krokami, on the SE coast, and of a mineral spring in the shallow sea water close to the beach of Saido at the NW part of the island.

The habitations, distributed among 20 hamlets and situated all along the coast, belonged to the two village districts of Higashi (Eastern) Sakura-jima and Nishi (Western) Sakura-jima, with the head offices respectively at Arimura and Yokoyama, the total population before the present eruption having been 23,738.

3. *Sea depth and mountain size.* The bay of Kagoshima, about 70 km in length and 20 km in width (Fig. 1), is a depression in the NS direction, doubtless having a connection with the formation of the Kirishima and Sakura-jima volcanic chain and is divided by the Sakura-jima distinctly into the southern and the northern portions. In the southern portion, there exists a sort of terrace with the water depth of up to 50 fathoms for the widths of about 4 and 2 km respectively along the western, or Satsuma, coast and the eastern, or Osumi, coast, while the basin at the middle has a depth of 100 to 122 fathoms. On the other hand, in the northern portion, which is surrounded mostly by steep coast, the depth of water is nearly uniform, ranging from about 70 to 107 fathoms. It is likely that the northern portion is similar in nature to the deep lakes which are found behind the sea-coast volcanoes of the Usu-san and the Tarumai-san, and its formation must be specially related to the history of the Sakura-jima; it being, in fact, in this nearly closed part of the bay that submarine eruptions produced 3 new islands (Kamizukuri-jima, or "islands formed by the gods") in 764 A.C., and again 8 new islands (the Anei-jima) in 1779–80 A.C. The western water way, or the channel between the Sakura-jima and the coast of the Satsuma peninsula, along which the city of Kagoshima is situated, is 2.3 to 4.1 km in width, with the maximum depth varying from 77 fathoms on the north to 38 fathoms on the south. The eastern water way is, on the other hand, reduced (now *blocked* up) to a narrow strait at Seto, on the SE corner of the island, where for the length of about 1.6 km the width was from 0.7 to 0.4 km, with the maximum depth of 45 fathoms, navigable for large men-of-war.

From the above accounts it will be observed that the Sakura-jima is a small volcano rising out of a shallow sea, the total volume of the island above the water level being 26.5 c. km, which will not be much augmented by adding that of the portion below the sea. In magnitude the Sakura-jima is not much different from the Usu-san,* situated on the Volcano Bay, but equivalent to only one eleventh of the Asama-yama (i. e., of the part above the plateau of Karuizawa on which it stands), and to one-fourtieth of the Fuji-yama, the volumes of these two last mountains being respectively about 290 and 1025 c. km. The smallness of size, coupled with the greatness of activity, probably means the existence of the lava reservoir at an exceedingly near depth of a few kilometres, and the comparative weakness of the mountain frame for resisting the internal explosive condition, as is also the case with the Usu-san; hence the indications of the unmistakable premonitary signs in the form of numerous earthquakes for several hours preceding the

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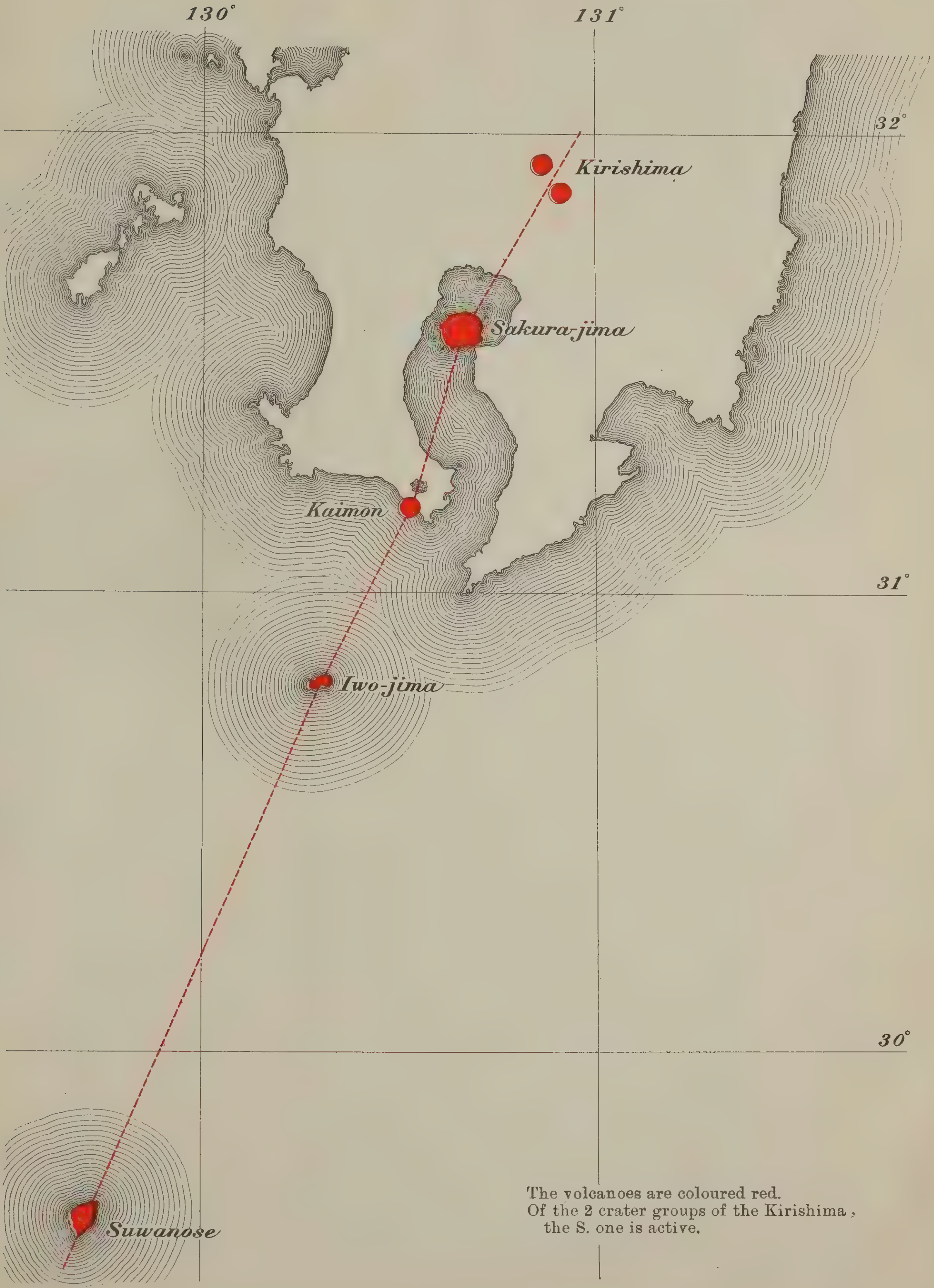
* An account of the Usu-san eruptions is given in the Bulletin, Vol. V, No. 1.

Fig. 1. Map showing the Positions of the Active Volcanoes in and off the S.W. Part of Kyushu.



The volcanoes are coloured red.
Of the 2 crater groups of the Kirishima, the S. one is active.

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Fig. lets are indicated by *red dots*. Pl. II.

i......Minami-dake.
i......Kita-dake.
a......Karasu-jima.

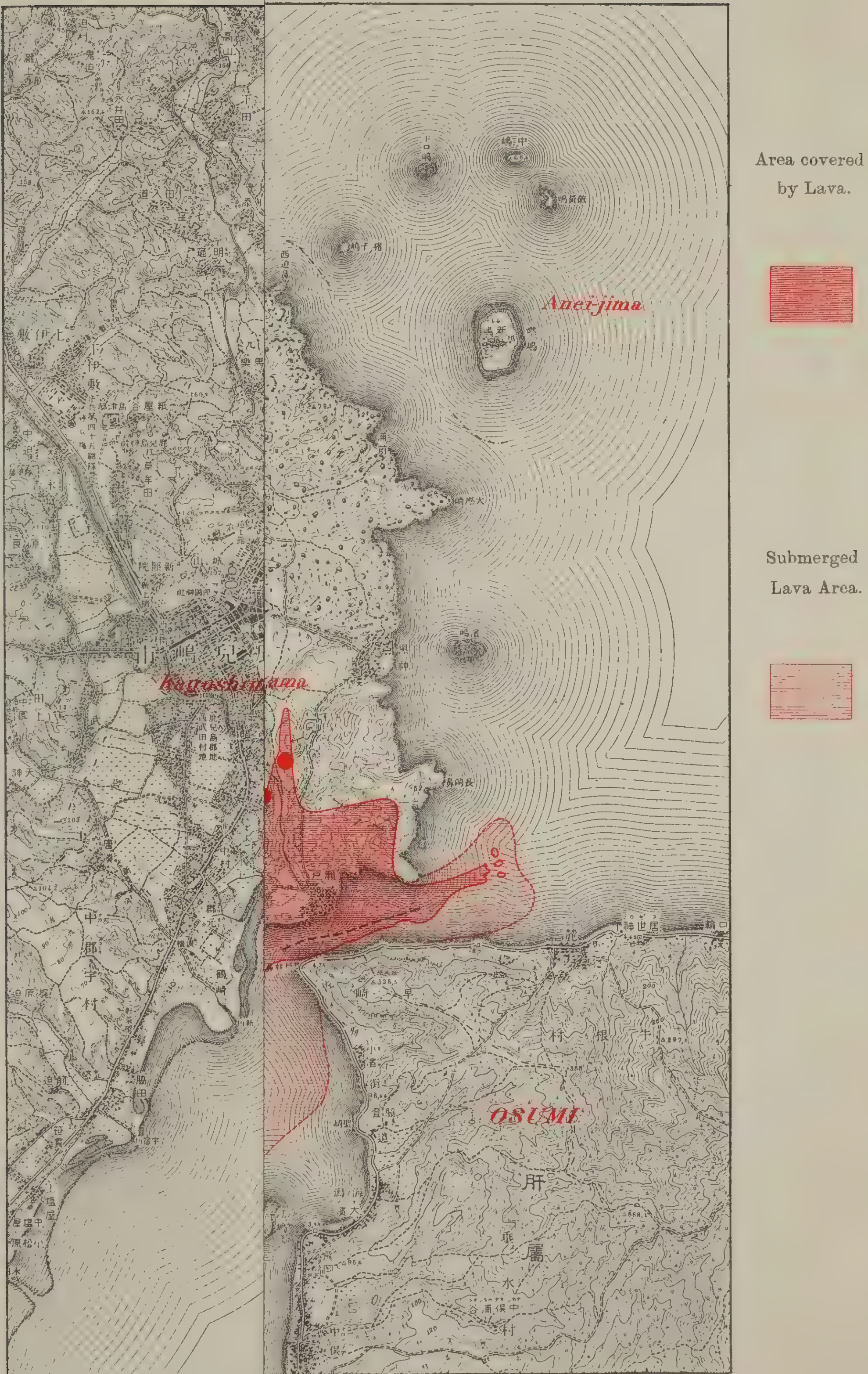
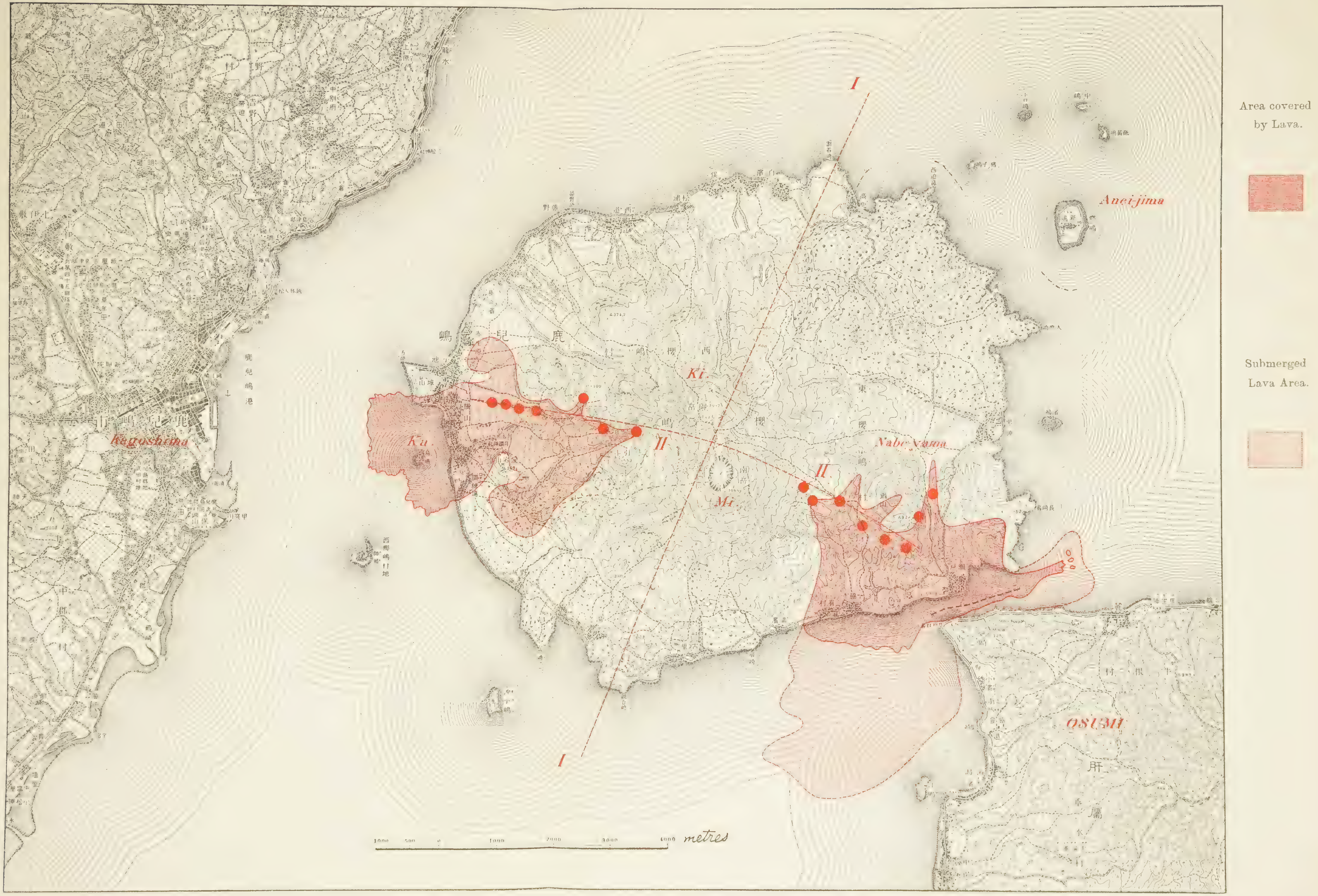


Fig. 2. Map of Sakura-jima, showing the New Areas covered by Lava and the approximate Positions of the Craterlets. (May 1914.)

New Craterlets are indicated by *red dots.*

Mi……Minami-dake.
Ki……Kita-dake.
Ka……Karasu-jima.



eruption in this year as well as that in 1779. Again, the eruptions were very intense and of a lengthy duration, and threw out a considerable quantity of fluid lava, pumice, and ashes, but the individual explosions were not quite so powerful as those of the Asama-yama, which caused not rarely some damage to the buildings 10 to 15 km distant from the crater by the violence of the air concussions.

4. *Simultaneous or successive activity of the different volcanoes. (Anei–Temmei–Kansei Epoch.)* The Japanese islands,* which form together a simple arc with steep descent on the convex side into the deep basin of the Pacific, may certainly be regarded as a system of volcanic chain or of earthquake zone, which is still undergoing the stress accumulation. When the latter reaches its limit, telluric disturbances may happen one after the other from various parts of the country in the form of great earthquakes or volcanic outbursts, as the case may be. The epoch of the most violent eruptions in the Japanese history was the interval of 14½ years in the Anei, Temmei, and Kansei periods, namely, between 1777 and 1792. In the first place, the O-shima Volcano began eruptions on Aug. 22nd, 1777 (the 6th year of Anei),** and lasted, with intermissions, till Dec. 18th, 1778, an enormous quantity of lava having been in the meanwhile poured out. Then followed, on Nov. 8th, 1779, (the 8th year of Anei), the great eruption of the Sakura-jima, attended by the remarkable lava outflows and formation of new islands; while the Aoga-shima, one of the Izu islands, commenced powerful outbursts on July 28th, 1780, and continued till April 18th, 1785. Before the activity of the latter volcano was brought to end, the Asama-yama broke out in strong eruptions since May 9th, 1783, (the 3rd year of Temmei), culminating in a terrible downrush of the ''volcanic avalanches'' on Aug. 5th.* Finally, the eruption of the Unsen-dake, in Shimabara (Kyushu), began on Feb. 12th, and terminated with a tremendous catastrophe on May 1st, 1792, (the 4th year of Kansei), when the entire southern slope of the Mae-yama slipped down and was precipitated as an immense avalanch of rocks and earth into the sea of Ariake, producing the great water disturbances, or *tsunami*, which resulted in the devastation along the coasts of the provinces of Hizen and Higo with the loss of nearly 15,000 lives.**

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* Limiting, for simplicity's sake, to the Nippon proper, or the 4 large islands of Honshu, Shikoku, Kyushu, and Hokkaido.

** See the Bulletin, Vol. VI, p. 13. The date of the eruption in question there was, by mistake, put on Aug. 21st, 1778.

Of the different mountains mentioned above, the Sakura-jima and the Unsen-dake are in Kyushu, while the three others, namely, the O-shima, the Aoga-shima, and the Asama-yama belong to the Fuji volcanic chain, which, rising from the Pacific basin, meets the Japan arc nearly at the middle transversally. Yet, in spite of the wide distance between the two groups, the different volcanoes were thrown into great eruptions one after the other. This characteristic is being repeated at the present epoch.

5. *Recent volcanic activity and Sakura-jima eruption.* An examination of the time distribution of the Asama-yama outbursts indicates the recurrence of the epochs of the greatest eruptive frequency at a mean interval of about $63\frac{1}{2}$ years. Thus the double length of $63\frac{1}{2} \times 2 = 127$, or, say, 130 years, may also be regarded as a possible period in the frequency variation of the eruptions; and it is noteworthy that the Asama-yama, the O-shima, and the Sakura-jima, which made no great outbursts since the Anei-Temmei times, have exhibited, just after the lapse of 130 years, again extraordinary activity within the recent years.

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* The Bulletin Vol. VI, p. 106.

** The Bulletin, Vol. I, p. 142.

In Dec. 1907, the Yake-dake, on the boundary of the provinces of Hida and Shinano, commenced explosions, while from 1908 the Asama-yama caused numberless earthquakes and eruptions, many of which latter were of considerable violence. In 1912, the O-shima made magnificent lava outbursts first in March-April and again in September-October. The explosions of the Yake-dake, which reached the climax of intensity in the summer of 1911, thence became gradually weaker, stopping completely since the summer of 1912. The eruption of the O-shima was also brought to an end in the spring of 1913; the Asama-yama, again, evidently approaching the last phase of its present activity from about the latter epoch. The recent eruptive energy of the Fuji volcanic chain manifested by the outbursts of these mountains thus drawing to a close, the Kyushu volcanoes were expected, in obedience to the sequence of events in the Anei-Temmei-Kansei periods, to be now in their turn brought into activity, when, from May 19th, 1913, local small earthquakes began to be frequently felt at the villages of Kakto, Massaki, etc., in the regions at the northern and western bases of the Kirishima-yama, which stands on the boundary of the provinces of Osumi and Hyuga and which had been quiet for the past 10 years. This sudden appearance of seismic disturbances was at once interpreted as foreboding its eruptions and marking the transference of the volcanic activity to Kyushu, and the present author sent, under the date of June 11th, 1913, a semi-official letter to Mr. T. Taniguchi, governor of the Kagoshima-ken, urging the necessity of setting up sensitive seismographs at the Kagoshima meteorological observatory* and carrying on continuous tremor observations, as the prefectural districts, with many volcanoes, are often shaken by strong earthquakes, probably also disturbed by volcanic micro-tremors, and especially as the Kirishima-yama was entering upon a period of activity. In the mean while, the seismic disturbances extended to the peninsular part of Satsuma, and at the end of June, a strong earthquake, with numerous after-shocks, took place in the vicinity of the village of Ijuin, some 16 km to the WNW from the city of Kagoshima. The Kirishima-yama broke finally in a strong explosion on Nov. 8th, followed by a second one on Dec. 9th, after which the present author made the intention, at the request of the governor of Kagoshima, of visiting the volcano in question in the course of the following month. On Jan. 8th of this year, the Kirishima-yama made the 3rd strong explosion, and 4 days later on the 12th, at about 10 a.m., there reached to his hand a telegram from the Kagoshima meteorological observatory, mentioning the occurrence of 337 earthquakes in the city between 6 o'clock in the same morning and 3 a.m., on the 11th. Startled by this intelligence which evidently indicated a wonderful increase of the telluric disturbances, the author was on the point of sending to Kagoshima a telegram giving the instruction of carefully watching the condition of the Sakura-jima, which could be the only cause of the unusual seismic phenomena, when came in the newspaper notice announcing the eruption of the same mountain.

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* The Kagoshima met. observatory is still furnished only with an ordinary Gray-Ewing-Milne seismograph.

6. ***Premonitary signs.*** Of great importance is the historical knowledge of the eruptions of different mountains, as we may thereby be much aided in considering the premonitary signs and the probable further course or consequence of outbursts from them. Unlike large destructive earthquakes, which originate along seismic zones, but are not repeated from one and the same centre, the eruptions of a given volcano take place usually from the central crater or from new side vents, being anyhow thus localized to the mountain itself. Hence it may be that the great outbursts from a given volcano at widely different epochs resemble each other more or less, both in the eruptive phenomena and in the precursory events. Thus, for instance, in the eruptions of the Usu-san in 1910, 1822, and 1663, the first smoke explosions took place each time 3 or 4 days after the commencement of the premonitary shakings.* In the case of the great Sakura-jima eruption of 1779, the earthquakes became very frequent from about 11 p. m. on Nov. 7th; on the next day at about 11 a.m., the well waters in the island boiled up, waters were squeezed or shot out from the different sea beaches, and the sea water was turned purple in colour; at 2 p. m. on the same day, a column of gray smokes was thrown up vertically from Futanaka on the top, followed after a short time interval by loud detonations and eruptions almost simultaneously both from the northern and the southern sides of the mountain; the black smokes, which turned the day into a darkest night, being mixed with terrible fires projected high into the heavens and traversed by lightnings in vertical and horizontal directions. This description of the Anei eruption of the Sakura-jima can, almost without alterations, be applied to the recent great disturbance of the island, which I now proceed to sketch briefly.

(I.) *Earthquakes.* In the early morning of Jan. 11th (1914), the people of the city of Kagoshima were generally aroused from sleep by an earthquake at about $3^h\ 41^m$, which was nothing else than one of the premonitary shakings proceeding from the

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* The Bulletin, Vol. V, No. 1.

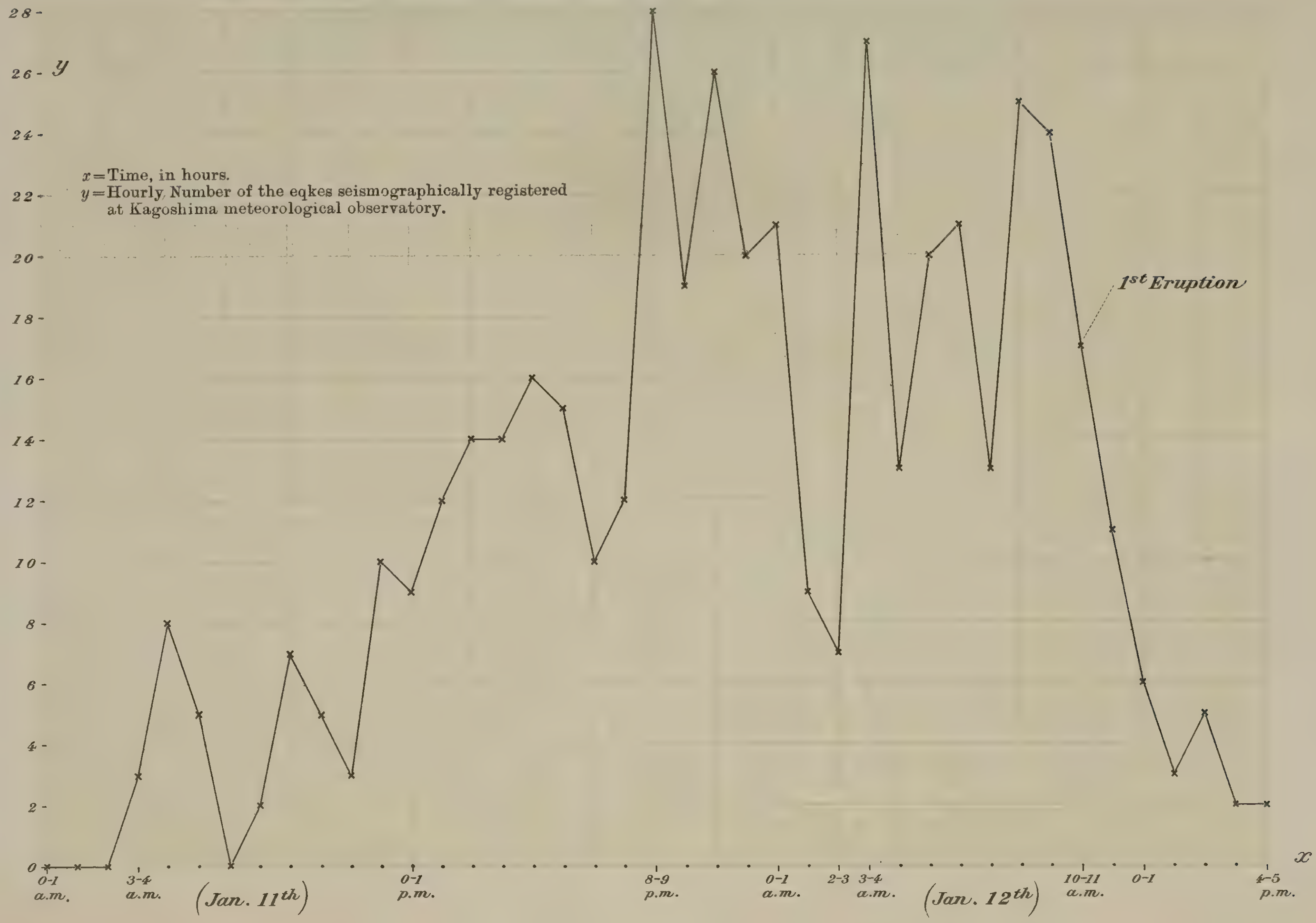
TABLE I. HOURLY EARTHQUAKE NUMBER OBSERVED WITH ORDINARY GRAY-MILNE-EWING SEISMOGRAPH AT THE METEOROLOGICAL OBSERVATORY OF KAGOSHIMA, JAN. 11TH—18TH, 1914.

Hour. \ Day.	11	12	13	14	15	16	17	18
0—1 a.m.	—	21	—	1	—	—	—	—
1—2	—	9	—	—	—	—	—	—
2—3	—	7	—	1	—	—	1	—
3—4	3	27	—	—	—	—	—	—
4—5	8	13	—	—	—	1	—	—
5—6	5	20	—	—	—	2	2	1
6—7	0	21	—	—	—	—	—	—
7—8	2	13	—	—	—	1	—	—
8—9	7	25	—	—	—	—	—	—
9—10	5	24	1	—	—	—	—	—
10—11	3	17	—	—	—	1	—	—
11—12	10	14	—	—	—	1	—	1
0—1 p.m.	9	6	—	—	—	2	—	—
1—2	12	3	—	—	1	—	—	1
2—3	14	5	—	—	—	1	—	1
3—4	14	2	—	—	—	—	—	1
4—5	16	2	3	—	—	—	—	—
5—6	15	2	—	—	—	—	—	—
6—7	10	1*	—	—	2	2	—	1
7—8	12	0	—	—	3	—	—	—
8—9	28	1	—	—	—	—	—	—
9—10	19	—	—	—	1	—	—	—
10—11	26	—	—	—	1	—	—	—
11—12	20	—	11	—	1	—	—	—

* After 6½ p.m. on the 12th, the register is imperfect, as the Gray-Milne-Ewing seismograph was damaged by the strong shock at that time.

Pl. III.

Fig. 3. Hourly Frequency Variation of the Earthquakes which preceded the Sakura-jima Eruption of Jan. 12th, 1914.



Sakura-jima, and was followed by numerous others. The annexed table gives the hourly numbers of the earthquakes registered with an ordinary Gray-Milne-Ewing seismograph between the 11th and the 18th, in January, at the Kagoshima meteorological observatory ($\varphi=31°36'N$; $\lambda=130°33'E$), which stands on a colline 120 metres in height outside the city, at a distance of 10.1 km to the N76°W from the centre of the Sakura-jima ($\varphi=31°35'N$; $\lambda=130°39'E$).

According to the above table, the average hourly earthquake frequency was 4.1 between 3 and 11 a.m., on the 11th; was increased to 12.4 during the next 9 hours, namely, between 11 a.m. and 8 p.m.; attained the highest value of 19.5 in the course of the further 14 hours between 8 p.m., on the 11th, and 10 a.m., on the 12th; the greatest hourly number of 28 and 27 having been reached respectively at 8-9 p.m., on the 11th, and 3-4 a.m., on the 12th. The total number of the earthquakes registered at Kagoshima between 3 a.m., on the 11th, and 10 a.m., on the 12th, was 418. In the Sakura-jima, the earthquakes, which were many times more numerous than in Kagoshima, seem to have occurred already from the night of the 10th, becoming stronger from about 3 a.m., on the 11th. At the village of Saido, situated at the NW coast of the island, 66 earthquakes were felt in the course of the single hour from the noon till 1 p.m., on the 11th, against the 9 shocks registered at the meteorological observatory of Kagoshima; the earthquakes, which contained a good proportion of vertical component, were generally announced by a sound like that caused by the fall of a heavy body on the ground, immediately followed by earth tremblings; at 9 a.m., on the 11th, the roads being already slightly damaged at several places. According to the account of the village headman of Higashi Sakura-jima, there was at $5\frac{1}{2}$

a. m., on the 12th, a most strong earthquake, accompanied by sharp vertical jerks.

(II) *Hot Springs, etc.* At the coast of Waki and Arimura, on the southern side of the island, waters began to be issued copiously from several places already in the early morning of the 12th, whose temperature was so high that people had, in time of low water, difficulty to walk across the beaches. At the same time, waters were bubbling up from among the sea, while the hot spring of Arimura was thrown up in jets to a height of 3 feet. It is highly interesting that an analogous phenomenon took place also on the opposite side of the island, namely, at Saido, where the issue of the natural cold spring waters at the beach was considerably augmented, the striking change having been noticed at about 8½ a. m. on the 12th by Mr. Hagiwara, head master of the village school, and many other people. Even on the 22nd of January, when Mr. Hagiwara returned back again to Saido, the waters were still copiously flowing out, such that the point of issue was some 20 metres more inwards than it had used to be. This locality is known as Yuno-saki, literally ''hot-water cape,'' it being likely that formerly there existed some hot springs, whose remnant may be the mineral spring refered to in § 2. One of the wells in the village had its water level, usually at a depth of 8 or 9 feet, raised on the morning of the 12th to within 5 feet from the ground surface.

(III.) *Smokes.* At about 8 a. m., on the 12th, a column of white smokes was suddenly shot up in the form of a pine tree from the top of the Minami-dake, while in the earlier hours of the morning, according to the observations from Kagoshima, several slender filaments of white vapours had been rising from above the layers of mists which shrouded the mountain. Again, according to the observations from the town of Tarumizu, on the coast of the province of Osumi, white smokes like clouds were floating at about 2 p. m. on the 11th about the SE mid-slope of the Sakura-jima.

The above were the unmistakable premonitary signs of the approaching catastrophe of the volcano, which previously had remained perfectly quiet and, since two decades or so, smokeless, except perhaps a feeble issue of some white vapours once or twice in the year. Taking alarm from the frequent earthquakes, the majority of the inhabitants began to escape from the island already on the 11th, partly westwards to the city of Kagoshima, and partly eastwards to the town of Tarumizu and the neighbouring villages in Osumi. The eruptions finally began on the 12th, at about 10 a. m. But, thanks to the timely warning taken by the people and the prompt and well directed measures of the prefectural authorities in despatching to succour the several steamers, which happened to be in port at the time, the whole inhabitants, over 23,000 in number, were all safely brought out of the danger, with the exception of the two clerks of the village office of Higashi Sakura-jima, who, together with the headman Mr. Kawakami, heroically remained till after the commencement of the eruptions and were drowned in attempting to swim across to the coast of Osumi. In the eruption of 1779, the number of the killed was, under similar circumstances, 144. The comparatively small amount of mortality in the different Sakura-jima eruptions is probably in a part due to the fact that the habitations are situated all along the coasts at some distances from the vents of the outbursts, and also to the fact that the latter do not attain full violence till some time after the commencement.

I can not here pass by without referring to the conduct of the director of the Kagoshima meteorological observatory, Mr. Y.

Katsuno, who rendered an invaluable service in faithfully carrying on the seismographical and meteorological observations throughout the trying hours of general confusion and panic, but who made a curious mistake in insisting till the very last moments on the supposed existence of the origin of the seismic disturbances in the opposite quarters, namely, in the direction of the Ijuin district some 16 km to the NW from the city of Kagoshima. This Sakura-jima eruption was indeed one, which could be predicted by the common sense at least one complete day before. As a successful instance of management with respect to a volcanic catastrophe, I may mention the eruptions in 1910 of the Usu-san, which were attended with no casualty in consequence of the compulsory measures taken by the police inspector, Mr. Iida, who ordered the inhabitants in the vicinity to leave the threatened districts, in strength of my lecture on earthquakes and eruptions, given in 1902, at the Police High School in Tokyo.

According to the graphical representation in Fig. 3, the first eruption took place about 13 hours after the occurrence of the absolute maximum hourly earthquake frequency at 8-9 p.m., on the 11th. It is difficult to explain why a marked frequency minimum did occur at 2-3 a. m. on the 12th. It seems probable, however, that this minimum in the seismic frequency, which must denote a partial decrease in the underground stress, was occasioned by some preliminary smoke emissions from the mountain top and sides, or jetting out of waters from the different places along the coasts.

7. *Eruptions.* The first outburst took place from the west side of the Sakura-jima at about 10 a.m., on the morning of the 12th, from a point above the Yokoyama-mura (height=about 500 m) followed after a short time interval of some 10 minutes by the outburst from the south shoulder of the Nabe-yama at the east side of the island. The outbursts, which were at the commencement accompanied by no special detonation, rapidly increased in magnitude and intensity.

According to the report of the Kagoshima meteorological observatory, which enjoys the full view of the Sakura-jima, red fires were seen at the base of the smoke column 5 minutes after the commencement of the eruption. The smokes ascended to a height of about 3,000 metres already at 11 a.m., while the lava blocks, several of which had tails of steam and gases, were observed to be thrown out thickly from 11. 30 a.m., when the *shoji* (paper-covered sliding doors) began to be shaken by the air vibrations. At 2. 30 p.m. the whole island was enveloped in white and black smokes, the eruptive noises becoming more and more intense till at 3. 30 p.m. the explosive detonations began to be heard.

The dense black smokes, which were, the weather being quiet, projected finally to a vertical height of over 20,000 feet above sea level, were traversed by electric lightnings in various directions, while the incessant air-quakes, cooperated, so to speak, with the most frequent seismic convulsions of the ground in the development of the awful catastrophe. The panic in Kagoshima was greatly augmented by various ridiculous reports, one of which, relating to the supposed far-reaching fatal consequences of the poisonous volcanic gases, enjoined the people to get beyond the limit of 20 km radial distance. This was most effective in driving the greatest majority of the seventy-thousand inhabitants out of the city, who experienced hardships and privations in the sudden exodus, each endeavouring to get away simply as far as possible, on foot, on vehicle, or by railways. Another supposed danger was in the possible inrush of enormous *tsunami* (tidal waves), which might sweep away the entire city. When the afternoon of the 12th passed away under such disquieting circumstances, a new and real source of danger appeared in the form of a strong earthquake, which happened at half past six o'clock and knocked down a great many of stone partition and fence walls, which abound in Kagoshima; a number of the dwelling and ware houses, mostly of stone construction, in the lower and soft-soil part of the city and in the new made-ground along the coast, were partially or entirely destroyed. After this earthquake, the volcanic noises and the projection of red hot lava masses became markedly stronger, and the "explosive stage" reached its full intensity between about 11 p.m., on the 12th, and 5 a.m. on the 13th, with the maximum at about 1 a.m. on the latter day. The detonations in Kagoshima during this interval were like those due to the quick firing of artillery pieces and were so loud that the prefectural officers had to stuff their ears with cotton. It was probably at this epoch that local hurricanes were produced by the eruption, which seem to have been specially strong at the west end of the island, in the neighbourhood of the Hakamagoshi, upon which were found transported large uprooted mandarin orange trees, 1 foot or more in stem diameter, and pieces of smashed wooden houses in the village of Yokoyama, situated at the east foot of the above named plateau hill, 72 m. in height. After 10 a.m., on the 13th, the violence of the explosions were greatly reduced, although continuing to happen still almost continuously. On the succeeding evening the volcano presented to the observers in Kagoshima the most magnificent sight, between about $8^h\ 15^m$ and $8^h\ 30^m$, the burning materials being shot high with brilliant display of lightnings, as it were, in a high pillar, and converting the whole mountain slope over Yokohama, from top to base, into one continuous zone of red hot masses. This was no other than the commencement of the outflowing of the lava streams. On the same occasion the houses in the village of Koike were burnt down. Thereafter the noises were greatly reduced.

Even as late as the 16th (January), when the author arrived in Kagoshima, the sight of the eruptions was very beautiful and grand, the state on the west side being much the same as in Fig. 7, which is a picture taken near the evening of the 15th from the harbour of Kagoshima. The more or less active eruptions on the west side of the island were brought nearly to end on the 25th of January; but those on the east, or the Nabe-yama, side have long kept up their energy, and are making occasional strong outbursts even at the present time (Aug. 1914).

Lava Streams. About 7 and 8 principal craterlets were formed respectively at the west and the east sides of the Sakura-jima, the uppermost one being in the former at an altitude of 500 m, and in the latter at an altitude of 400 m. The lava which flowed out from both of these groups was, like that of the Asama-yama, of very little fluidity, so that it is generally broken up into loose angular blocks. The main branch of the lava stream on the west side seems to have run down before 7 a.m. the next day through a distance of 2,000 m, or in about 12 hours already to within 500 m of the coast, reaching the same on the morning of the 16th. Thus the mean velocity of the descent of the lava stream in question was about 45 m per hour during the 1st $2\frac{1}{2}$ days. The lava stream, which continued its forward progress into the sea, sending up an infinite number of small columns of pure white water vapours, reached at about the noon of the 18th the small Karasu-jima, whose height was 20 metres and was at a distance of about 600 metres from the coast; giving the velocity of the lava motion of about 21 m per hour in the time interval between the 16th and the 18th. When examined on the 20th, this islet had entirely disappeared under the lava in such a way that it was difficult to identify its former position. On Jan. 22nd, the lava stream was moving, at the south base of the Hakamagoshi, with a speed of about 1 foot per hour.

On the other hand, the lava streams from the eastern, or Nabeyama side, craterlets quickly reached the comparatively deep Seto Strait between the SE end of the Sakura-jima and the Sakkabira promontary of the province of Osumi, and, getting under the sea, was, when seen on the 16th (January), vigorously sending up masses of dense white smokes, the surface water temperature being 49°C (measured on Jan. 23rd). The strait, whose width was narrowed by the lava to about 20 metres on Jan. 24th, was finally blocked up on the 29th of the same month, the Sakura-jima island being thus converted into a peninsula. When viewed at the commencement of April last, the lava mass filling the strait was bulged up into hills 50 m or more in vertical height, still steadily pressing hard upon the former coast of Osumi. (See Fig. 4.)

Areas covered by Lava. Fig. 2 indicates the areas covered at the commencement of May last by the lava which streamed out from the two groups of the craterlets, the forms of the protuberances in the sea, both above and below water, being based on the surveys and soundings undertaken by the Hydrographical Department of the Imperial Navy. On the west side, the lava layers, whose maximum thickness or height was in the earlier days about 60 m, completely buried under them the villages of Yokoyama and Akamizu, reached the extreme extension of 4.8 km in the EW direction, and extended 1,400 m into the Kagoshima Channel. As the depth of the latter, between the city of

Kagoshima and the Hakamagoshi and the former isle of Karasu-jima, is generally less than 24 fathoms, or 44 metres, there was on that side no marked submarine extension of the lava, the top of whose end edge stands high up or is just visible out of the water surface. On the south-east coast of the Sakura-jima the three villages of Seto, Waki, and Arimura were all buried under the lava streams, which flowed, on the north, along the west shoulder and into the crater, of the Nabe-yama. A small hill, 103 m in height, on the SE coast, which had not been covered by the lava at the end of January, was found entirely buried under it at the commencement of April. As the sea off the SE coast of the Sakura-jima was 70 to 90 fathoms (128 to 165 m) in depth, the protuberance of the lava stream into the bay, which remains above the water level, is only about 700 m in maximum width, but the under-water extension is considerable and has the extreme distance of 3.4 km between the SSW end and the above-mentioned former coast hill.

Even at the distances of 2.0 to 2.3 km from the SE coast of the Sakura-jima under consideration, there were marked changes in the water depth revealed by the soundings; thus, for instance, at a point was found a depth of 25 fathoms instead of the former depth of 84 fathoms; at a second point, 26 fathoms instead of 88 fathoms; at a third, 36 fathoms instead of 96 fathoms, etc. These results seem to point to the conclusion that the submerged layer of the lava stream is in its middle and southern parts 50 to 60 fathoms or 90 to 110 metres in thickness. For the west, or Yokoyama side, lava stream, the thikness of the portion projecting into the sea may be taken to be about 30 fathoms or 55 metres. The approximate areas of the lava covered tracts are as follows:—

Area.	Western, or Yokoyama, Side Lava Stream.	Eastern, or Nabe-yama, Side Lava Stream.	
Land (i. e. former land) area covered by lava.	5.91 sq. km.	5.25 sq. km.	Sum, 7.44
New lava area above water (or coast increase).	2.42	2.19	
Submerged lava field.	—	7.97	
Sum.	8.33	15.41	

Thus, the total area of the eastern lava field, which is 15.41 sq. km and of which 7.97 sq. km belongs to the submerged portion, is nearly double that of the western, namely, 8.33 sq.km. The sum of the areas of the eastern and the western lava fields is 23.7 sq.km, which is equivalent almost exactly to one-third of the area of the Sakura-jima. Assuming the mean thicknesses of the entire western side lava field and of the land portion of the eastern side lava field to be each 40 m, and that of the rest of the latter to be 100 m, we get the following results:—

(Volume)
Western lava field: ....0.333 c.km.
Eastern lava field: ....1.226 ,,
Sum : ....1.559 ,,

The estimated total volume of the lava, which flowed out from the two sides of the Sakura-jima, is thus about **1.6** c.km, and equivalent to about one-seventeenth of the volume of the mountain, which is =26.5 c.km. The enormity of the Sakura-jima disturbances will be realized from a comparison with the great Temmei (1783) eruption of the Asama-yama; the area and the volume (under the assumption of the mean thickness of 40 m) of the "Oni-oshidashi" or lava stream on that occasion being 6.9 sq.km and 0.27 c.km, which are equal respectively to $\frac{1}{3.4}$ and $\frac{1}{6}$ of the corresponding quantities of the present Sakura-jima eruption. Moreover, in the Asama-yama catastrophe above refered to, the volume of the lava outflow was only 1/1,000th of that of the mountain.

Precipitation of Lava Fragments and Ashes. The villages of Koike and Akobaru, situated on the west coast to the north of the Hakamagoshi, were, although outside the lava stream areas, completely crushed, burnt, and buried by the showers of more or less pumiceous hot lava fragments projected from the craterlets. The scene in these neighbourhoods was desolate and barren in the extreme; the stones, which also smashed the trees in terrible conditions, having made an innumerable number of the so-called conical holes of various dimensions on the Hakamagoshi and in the tracts adjacent to its N. and E. bases. These facts, in conjunction with the probable gush of hot volcanic gases mentioned in p. 16, seem to indicate that the local explosive effects attending the eruptions were specially strong at the west side craterlets. The precipitation of pumice and ashes was very abundant in the eastern part of the island, being deepest at and about Kurokami, where it amounted to 6 feet or more and buried the houses nearly up to the roof. Fig. 5 illustrates how the gate of the village temple had the two upright stone columns, some 8 or 9 feet in height, buried under the pumice and ashes, only the two horizontal top beams remaining in the air. On account of the prevalence of the westerly winds in the higher atmospheric region all the year round, the ashes of the different volcanic eruptions in Japan are generally carried eastwards, whatever the surface winds may be. Thus, the ashes of the great Sakura-jima eruption of 1779 reached Osaka, Nagoya, and Yedo (Tokyo). On the present occasion, the ash-precipitation reached the Bonin Islands on the SE, and extended to the NE over Kyushu, Shikoku, and the whole of the Main Island to the west of Mito and Utsunomiya, the extreme eastward radial distance being over 1,200 km. Thus the ash-precipitation was very slight and under 3 mm in Kagoshima situated close enough to the west of the Sakura-jima, while it was very heavy in the northern and central parts of the province of Osumi, the amount ranging from 3 or 5 inches to over 3 feet. The principal axis of the ash-precipitation zone extended from the Sakura-jima in the direction of E. slightly S. to the vicinity of the town of Shibushi on the Ariake Bay. Making the planimeter estimations of the areas enclosed by the different iso-precipitation curves drawn on a map, based on the measurements of the thickness at a number of places in the S. part of Kyushu, the total amount of the pumice and ashes, which fell in the latter only, comes out to be about 0.62 c.km, equivalent to 40% of the total volume of the lava outflow. This is a sufficiently large quantity, which, if distributed over the whole extension of the city of Tokyo, about 80 sq. km in area, would give a mean thickness of about 8 metres.

The total sum of the volumes of the pumice and ashes and of the lava outflow thus amounts to 1.56+0.62=**2.2** c.km, which is equivalent to **1/12**th of the volume of the whole mountain.

The specific gravity of the ashes, which were acidic, determined from the specimens collected in Kagoshima and the Sakura-jima, varied from 0.9 to 1.2, giving the mean value of 1.0. Again, the specific gravity of the lava pieces and bombs found at the west, or Yokoyama, side varied mostly between 1.06 and 1.63, with the mean value of 1.4; while that for the specimens from the eastern, or Nabe-yama, side, was between 1.92 and 2.81, with the high mean of 2.4.

8. ***Strong earthquake and small tsunami.*** In the strong

Sakura-jima Eruption of 1914.

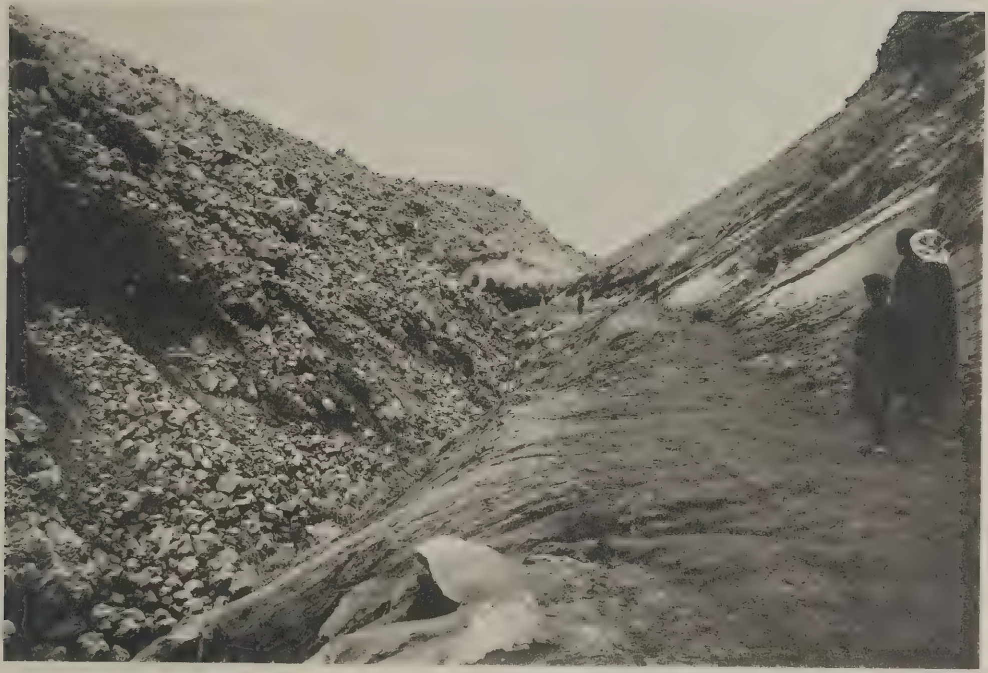


Fig. 4. Blocking up of Seto Strait, originally 0.7 km in width and 45 fathoms in depth. The right-hand side slope is the former coast of Osumi, while the left-hand side hill, over 50 m in height, is the lava which flowed down from the Sakura-jima.
(April 10th, 1914. F. Omori, phot.)

Sakura-jima Eruption of 1914.

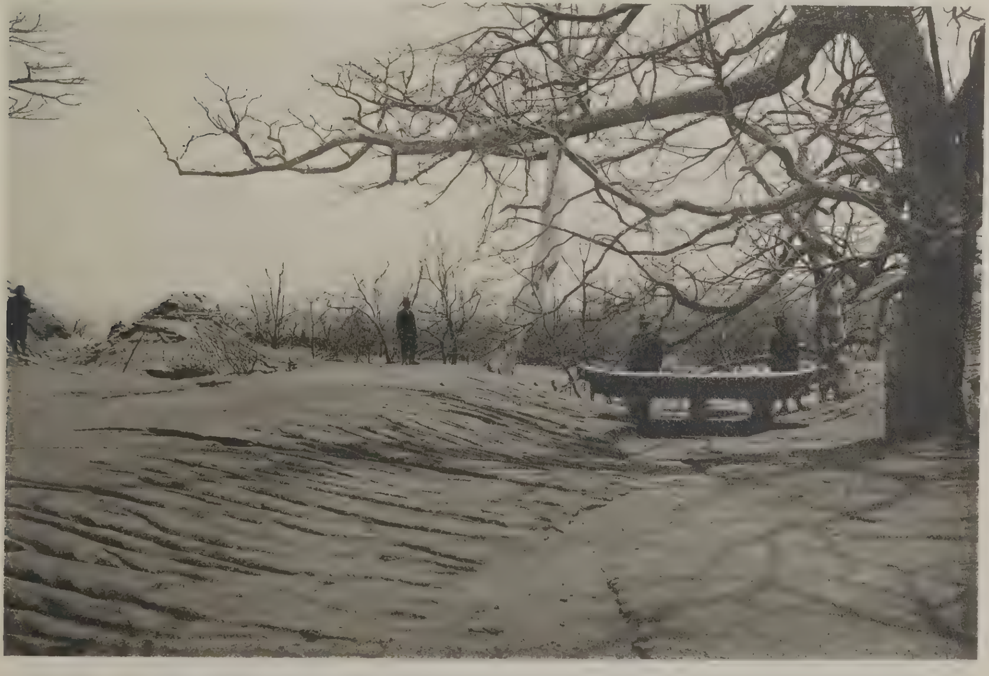


Fig. 5. Scene at the village of Kurokami, on the E. coast of Sakura-jima. The thick precipitation of pumice and ashes buried the two posts of the stone "torii," or temple gate, 8 or 9 ft. in height, leaving only the horizontal top beams in air. Of the houses, only the roofs are left above the ashes. (April 9th, 1914. F. Omori, phot.)

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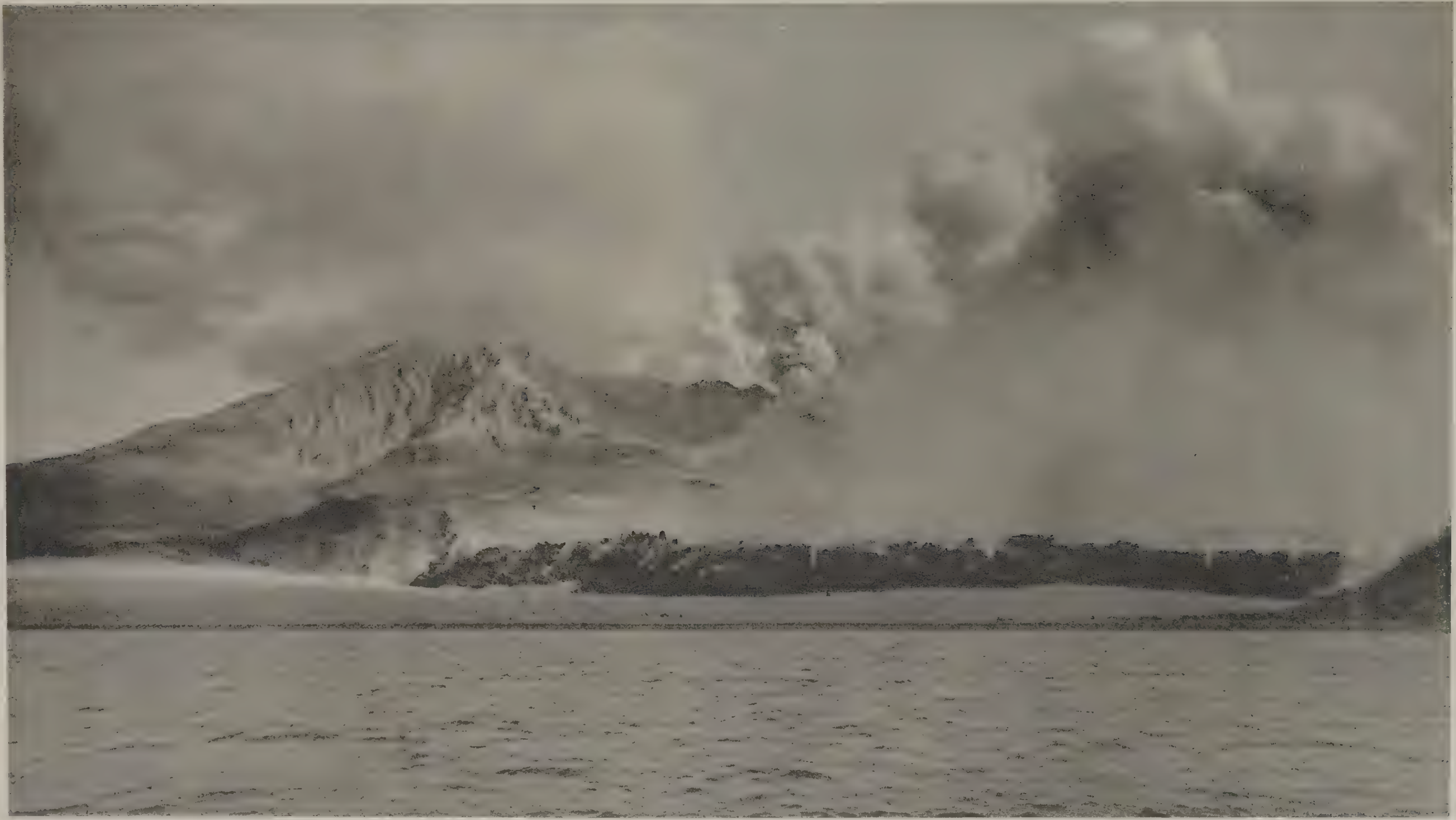

Fig. 6. **Eruption of Sakura-jima,** seen from the NW, showing the **lava outflow** at the front. The principal explosions are taking place from the back, or Nabeyama, side.
(Jan. 23rd, 1914. F. Omori, phot.)

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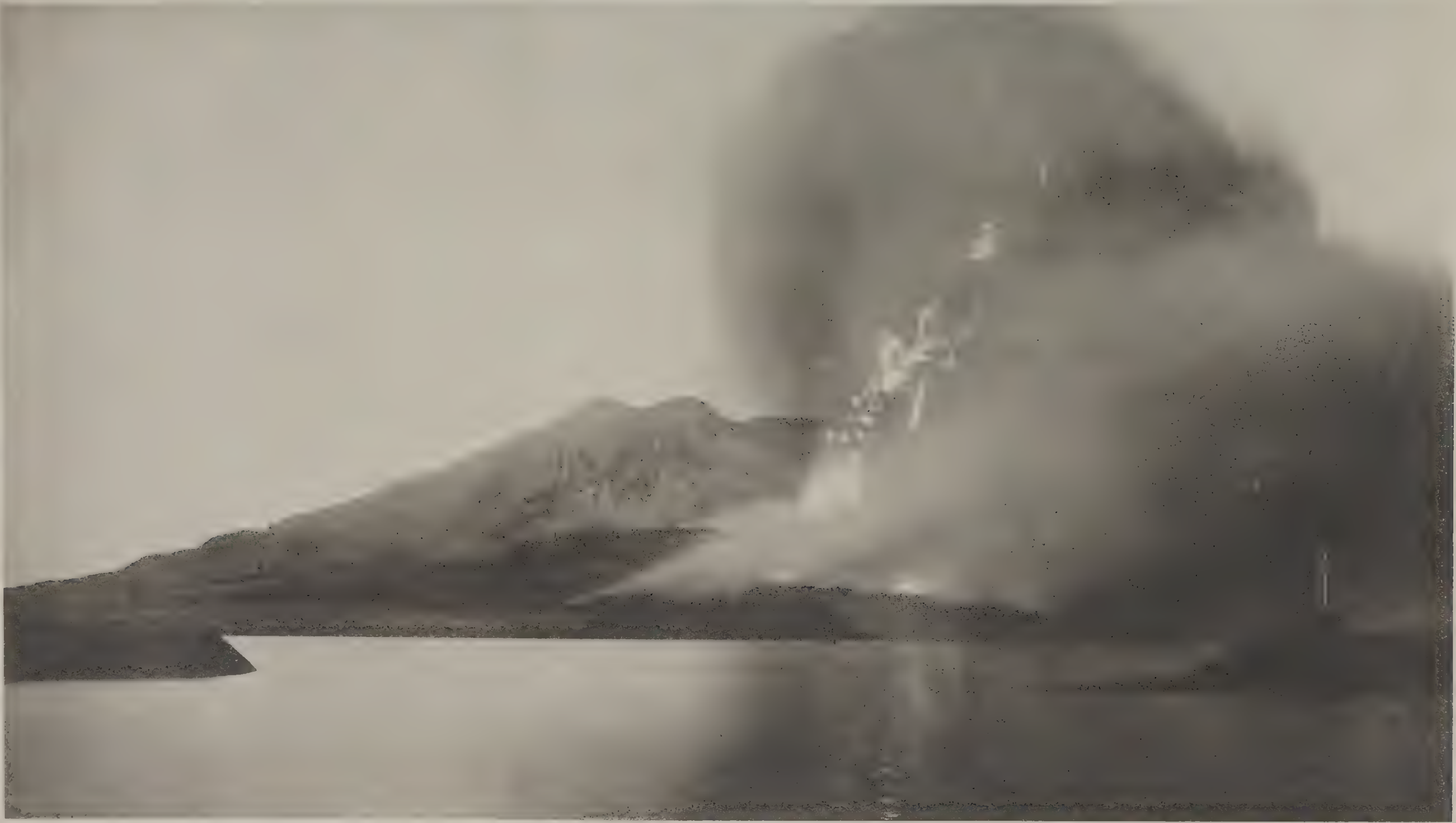

Fig. 7. Eruption of Sakura-jima. View taken in the evening of Jan. 15th, 1914, from Kagoshima quey, showing the luminous lava projection and electric lightnings. (Yuki, phot.)

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earthquake of Jan. 12th, at half past six o'clock in the evening, were killed 7 persons walking in the city streets by the outward overturning of stone fences, and 12 others, on the way of escape to country places, by the crumbling down of high perpendicular roadside cliffs of soft tuff at a place called Tenjinga-seto, outside of Kagoshima. This seismic disturbance, whose preliminary tremor reached Tokyo at 6^h 30^m 21^s p.m., was obviously of the volcanic nature or relation, being, however, unusually large in magnitude. Judging from the tromometer diagrams obtained in Tokyo, it is evident that the Kagoshima (or Sakura-jima, provisionally) earthquake in question must have been several times larger in magnitude than the strong Asama-yama earthquakes of May 26th, 1908,(1) and of July 16th, 1912, or of the strong Usu-san earthquake of July 24th, 1910, at 3. 49 p.m.,(2) which seemed to represent the limiting intensity and size of a volcanic earthquake. A special character of this Kagoshima earthquake is that the intensity of motion was nowhere very severe, the seismic damage in the Sakura-jima itself being, probably on account of the rocky nature of the ground, considerably smaller than in the lower part of the city of Kagoshima. It is thus evident that the earthquake must have been of very deep origin and was probably the result rather of the stress accumulation along the whole volcanic chain in the southern Kyushu, being not at all a simple local shock connected only with the eruptions of the Sakura-jima. This supposition seems probable, as one month later, on Feb. 13th, at 3.37.19 p.m.(3) there took place an earthquake also of no insignificant magnitude during the activity of the Iwo-jima, another of the same volcanic chain. Strong volcanic earthquakes may possibly be divided into the two categories of (i) local shock, necessarily of shallow focal depth, and (ii) extensive earthquake, of great depth. In both of these cases the surface intensity of the seismic motion would not be so high as in great destructive earthquakes of tectonic origin.

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(1) See the Bulletin, Vol. VI, Figs. 36 and 37.

(2) See the Bulletin, Vol. V, p. 15.

(3) Time of earthquake occurrence indicated by the tromometers in Tokyo.

In the city of Kagoshima, which is situated to the west of the Sakura-jima, the earthquake damage done to the various structures indicated very clearly the longitudinal nature of the shock. Thus, the stone fences, which were in the E-W directions, even though of very unstable dimensions, remained standing, while those in the N-S directions were very often *overturned.* On the other hand, in the cases of the wooden houses with plastered or paper-covered walls, the damage was of a different nature: the walls in the E-W directions were much broken by the two systems of *mutually rectangular cracks*, while those in the N-S direction remained mostly intact. According to the ordinary seismograph diagram obtained at the Kagoshima meteorological observatory, the very first earthquake displacement of the strong shock under consideration was directed toward WNW, or radially away from the Sakura-jima.

The 12th of January happened to be the day of full moon and the tide was high in the evening when the strong earthquake took place. Probably 1 or 1½ hours after the occurrence of the earthquake, the waters in the harbour of Kagoshima, whose level was then only about 1½ feet below the top surface of the quey wall, flowed a little over the latter and partially washed the strand streets, a few boats being thereby damaged. This disturbance of the sea waters is to be regarded as a small *tsunami*, whose direct cause was, however, not in the strong earthquake before mentioned, but probably in a small sudden settlement or depression of the bay bottom. (See also § 10.)

TABLE II. DAILY NUMBERS OF THE ERUPTIONS AND EARTHQUAKES OF THE SAKURA-JIMA, INSTRUMENTALLY REGISTERED AT KAGOSHIMA, JAN. 16th TO FEB. 7th, 1914.

Date. (1914.)	Outbursts.		Volcanic Earthquakes not accompanied by Eruptions.		Earthquakes of neighbouring origin.	
	Stronger.	Weaker.	Larger.	Smaller.	Larger.	Smaller.
January, 16*	13	—	1	—	—	—
17	67	1	4	5	2	—
18	53	84	7	9	4	—
19	74	39	1	2	—	—
20	65	78	1	2	2	—
21	37	77	2	4	1	—
22	29	93	3	—	1	—
23	34	82	1	1	—	—
24	40	78	—	1	—	—
25	36	63	3	1	1	—
26	29	101	1	—	—	—
27	35	136	—	4	—	—
28	14	148	2	—	—	—
29	17	147	3	5	—	—
30	1	144	—	3	—	—
31**	5	130	1	2	—	—
February, 1	6	117	2	7	—	—
2	4	108	—	1	—	—
3	2	60	—	2	—	—
4	—	105	1	4	—	—
5	—	82	—	—	—	—
6	2	160	2	2	—	—
7	1	63	1	—	—	—

* Registration commenced from 6^h 6^m p. m.

** Volcanic tremors were very marked between 9 a.m. and 10 p. m.

9. *Tromometer observations of eruptions.* A 200-times magnification two-component horizontal tremor-recorder, which the author took with him at his first visit to the Sakura-jima in January, was temporarily set up on the solid stone foundation in the instrument room of the Weight and Measure Department, in the Prefectural compound, and the observation was, under the care of my assistant Mr. Kurosaka, started on the 16th of the same month and continued till Feb. 8th, when the seismograph was removed to the village of Furusato in the Sakura-jima. The result of the registration is embodied in Table II, which is the list of the daily numbers during this interval of the larger and smaller volcanic eruptions and of the non-eruptive volcanic earthquakes, and of shocks of the neighbouring origin; the photographically enlarged illustrative diagrams being given in Figs. 8 and 9.

The strong outbursts, or large disturbances, which were at first very numerous, with the daily frequency of 53 to 74 between the 17th and the 20th (January), thereafter markedly decreased, the frequency between the 21st and the 27th being 29 to 40. After Jan. 28th, the decrease was equally remarkable, the mean daily frequency during the next 11 days being only 4.7. On the other hand, the frequency of the weak outbursts, or small disturbances, indicated a tendency of varying in inverse proportion to that of the other disturbances. The daily number of the non-eruptive volcanic earthquakes also shows a tendency of alternating the epochs of maximum frequency with those of the strong eruptions. I must here state that the *large disturbance* means here simply an outburst whose earthquake motion was comparatively large (double amplitude=0.1 mm or so), and the *small disturbance* one whose earthquake motion was small (double amplitude=0.01 mm or so); in either case, no reference being made to the intensity of the sound. A noteworthy fact is that the explosions accompanied

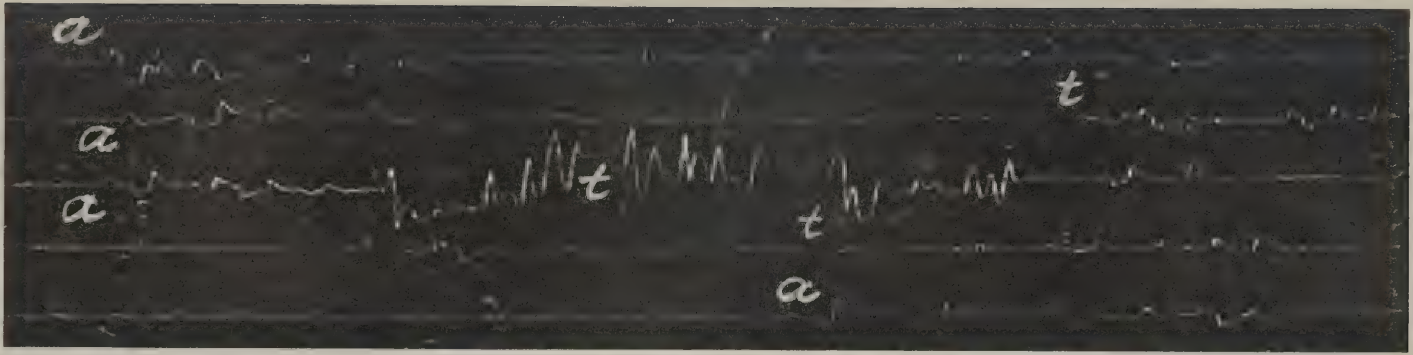

Fig. 8. Tremor recorder observation of Sakura-jima Eruptions at Prefectural Compound, Kagoshima, giving the longitudinal component diagram of "**Small Disturbances**" on Jan. 20th, 1914. Magnification = 673. Time scale: 1 Minute = 188 mm.

a......Commencement of an eruption. t......Minute (time) cutting.

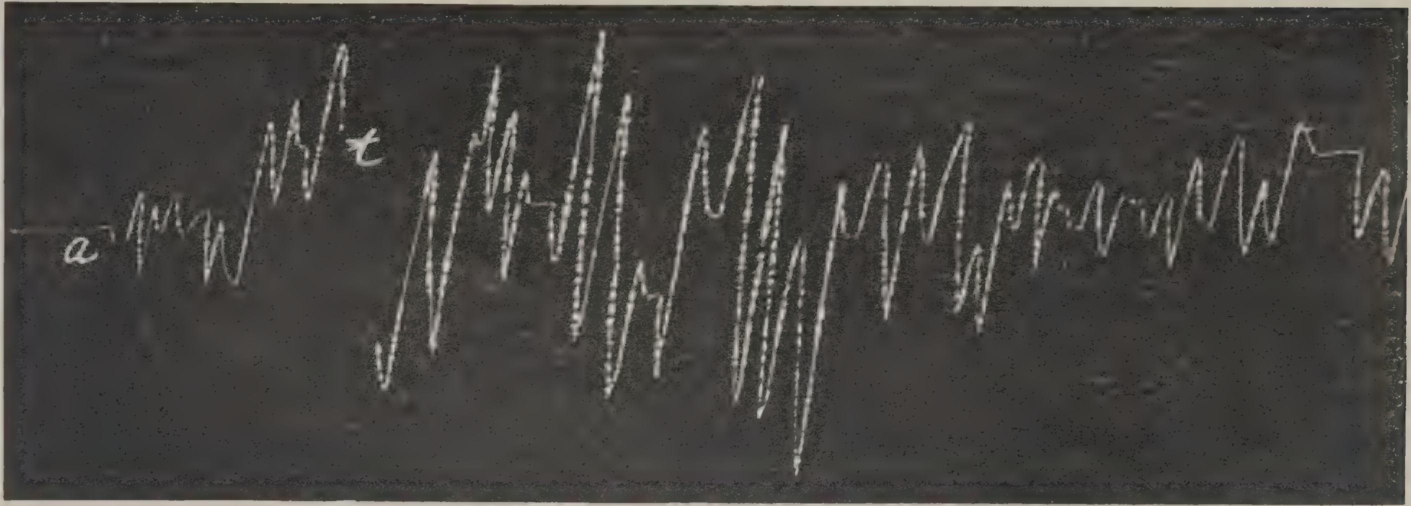

Fig. 9. Tremor-recorder observation of Sakura-jima Eruptions at Prefectural Compound, Kagoshima, giving the longitudinal component diagram of a "**Large Disturbance**" on Jan. 20th, 1914. Magnification = 820. Time scale: 1 Minute = 225 mm.

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by very loud detonations, like, for instance, the outburst from one of the Nabe-yama side craterlets on Feb. 7th, at 11^h 25^m a.m. which startled the inhabitants of Kagoshima and neighbouring places, caused generally very small amount of the earthquake motion almost undistinguishable from the micro-tremors.* Thus, in the present case there are two kinds of the eruptions, as follows: (i), explosion with a loud detonation, which causes only a very slight amount of seismic effects; and, (ii), non-detonative eruption, which is accompanied by comparatively large earth vibrations. It is likely that the (i) eruptions produce the loud noises by suddenly rupturing or breaking open the partially solidified lava bottoms of the craterlets and are more of the nature of the surface action, while the (ii) eruptions are more important phenomena and consist in powerful projections of ashes and gases along pre-existing channels of deep extension. It thus follows that the mere abundance of the loud detonations, which long continued to disquiet the people of Kagoshima from time to time, is to be represented by the high frequency of the small disturbance, and by no means signified any material augmentation in the activity of the Sakura-jima. If the frequency of the "large disturbances" be assumed to give a measure of the degree or amount of the eruptive activity of the volcano, it will be seen from the above list that the latter is steadily tending back to the equilibrium condition. The decrease rate of the large disturbances was such that at the end of March the frequency was only about $\frac{1}{6,000}$th of that on Jan. 16th-17th, or roughly some $\frac{1}{10,000}$th of what existed at the commencement of the eruptions.

10. *Effect on level of bay water and depression of coast.*

---

*) Similar peculiarity was observed to a certain extent also in the case of the Asama-yama eruptions. (See the Bulletin, Vol. VII, No. 1.)

According to the tide gauge readings at the Kagoshima harbour in 1903 and 1904, the highest sea level was 12.3 *shaku*(1) which took place on Sept. 11th and Oct. 10th, 1904, the maximum daily range, or the height difference between the low and high waters being about 11.5 *shaku*. After the commencement of the present eruptions of the Sakura-jima, however, there took place abnormal disturbances in the sea level, a height of 12.2 *shaku* having been realized on the occasion of the high tide of March 13 (17th lunar day), inuandating the lower coast parts of the city of Kagoshima and causing some damage to the salt-fields along the beaches of the town of Kajiki and other places. This overflow of the sea waters, quite unusual except in the autumn months, seems to have been the consequence of a general elevation of the mean sea level in the northern part of the bay, the difference between the recent ebb and flow at Kagoshima being 10.4 *shaku*, or 1.1 *shaku* less than the maximum limit before found. Thus, according to the observations started since the 14th of February, 1914, by the Prefectural Engineering Department, the approximate mean height of the sea surface at the same place during the rest of the month was 7.16 *shaku*. It was 0.51 *shaku* lower in March, there being no marked variation between the latter and May, as follows:—

Month.	Mean Monthly Height of Sea Level (Kagoshima Harbour) in	
	1914.	1903 and 1904.
February.	7.16(2) *shaku*	5.95 *shaku*
March.	6.65	5.95
April.	6.54	6.24
May.	6.69	6.23

---

(1) 1 *shaku*=1 metre /3.3=1 foot very nearly. (2) After the 14th.

From the above table it will be seen that the mean monthly level in February this year was 1.2 *shaku* (=36 cm) higher than in the corresponding month in 1903 and 1904, the difference having been reduced to the mean amount of about 0.5 *shaku* (=15 cm) in March to May. This latter residual amount may denote the amount of the depression of the coast of Kagoshima (see below), while the greater part of the elevation of the mean level during February, and also possibly in January after the eruption, was probably the effect, as Prof. A. Imamura insists, of the temperature increase of the bay waters through the inflow of the lava streams and other circumstances. Anyhow the marked temporary elevation of the sea-level in the bay, also temporarily the case after the eruption of 1779, seems to have already in the greater portion subsided.

Comparing the results of the levelling now being repeated, at the suggestion of the Imperial Earthquake Investigation Committee, by the Military Survey Department with the heights determined in 1892, it follows that there has been a depression, whose amount is about 0.2 m at the coast of Kagoshima and is increased up to 0.67 m at a small promontary about 10 km northwards along the coast.* The greater portion of the depression thus found may possibly be the result or precursor of the great recent convulsions of the Sakura-jima.

11. *Arrangement of craterlets.* (Fig. 2.) The different new craterlets on both sides of the Sakura-jima are arranged evidently along a zone (II II), which extends through the centre of the island in an WNW and ESE direction, and to which also belong the extinct parasitic cone of the Nabe-yama on the SE and the dome of the Hikinohira and the (now covered up) Karasu-jima on the W. This zone, whose original formation probably dates back to the epoch of the construction of the mountain itself, is approximately at right angles to the line I I, which connects the Sakura-jima with the active Kirishima-yama on the NNE and the dormant Kaimon-dake, or Satsuma Fuji, on the SSW. It is hereby to be noticed that the line I I represents a part of the extensive South Kyushu volcanic chain and is, in this respect, of primary importance in comparison to the zone II II, which, being none of such a chain, is to be regarded as marking a system of secondary fracture or crack limited to the island itself.

---

*For the communications of these preliminary results I am indebted to the kindness of Mr. M. Sugiyama, of the Military Survey Department.

The formation of numerous craterlets on two opposite flanks of the island was also the case with the eruptions of 1779 and 1476; it being obviously easier for the eruptive energy of the Sakura-jima to find vents at or near the base of the mountain than to push up the internal lava to its top.

12. ***Course of eruptive phenomena.*** It is certainly a very difficult problem, involving great amount of responsibility toward the public for several years to follow, to forecast the future condition of a volcano in complex activity with reference to the possibility or non-possibility of the repetition of the strong outbursts and the existence or non-existence of danger to the inhabitants at the mountain base. Yet, as a seismological member of the Imperial Earthquake Investigation Committee, I had to give out in distinct forms my opinions on these questions as soon as possible, in relation to the outbursts of the Sakura-jima, which were obviously to be continued for several months. With respect to the city of Kagoshima the matter was perfectly simple, as explained in the next §. It was, however, after a long consideration that the author decided, on the 20th of January, or one week after the commencement of the eruption, to allow the fugitives from Nojiri, Furusato, etc., on the SW coast, and those from Take, Fujino, etc., on the NW coast of the Sakura-jima, to return on their own choise to the respective villages, where the ash-precipitation had not been excessive; giving them caution to be careful should frequent or strong earthquake shocks be repeated again in the island. Now, the eruption of Nov. 8th, 1779, (§ 2), was followed, in the course of one complete year beginning with Nov. 21st, or the 14th day from the date of commencement of the disturbance, by the formation of the 8 new islands off the NE side of the Sakura-jima, each time accompanied by sea water disturbances resulting in a small *tsunami*. The possibility of the similar submarine eruptions following the recent catastrophe gave the people of Kagoshima some uneasiness, giving rise at the end of January even to a false report of the appearance of a new island off the SW coast of the Sakura-jima. The reasoning by which I denied the probability of the repetition in the present instance of this particular sort of volcanic phenomena, was as follows:—The craterlets in the eruption of 1779 were formed on the S and NE sides of the island, or roughly parallel to the general direction I I (Fig. 2) of the volcanic chain, along which, and especially, in the northern part of the bay, between the two volcanoes of the Sakura-jima and the Kirishima-yama, submarine eruptions may occur, as in 1779 and 764; while in the present case, the craterlets have been formed along a secondary line of weakness, and not along a volcanic chain, implying the impossiblity of occurrence of new eruptions from points on extention either toward Kagoshima or toward Osumi. As a matter of fact, there has been so far no formation of a new eruption island.

13. ***City of Kagoshima and eruption.*** The city of

Kagoshima, although near enough to the Sakura-jima, is in reality in a position not to be damaged by the eruptions of the latter, and, on receipt of the news of the first eruption on the 12th (Jan.), I sent at once telegrams to the governor of the Kagoshima prefecture and to the editor of the daily paper, the ''Kagoshima Asahi,'' to the effect that in Kagoshima, safe from the visitation of a great destructive earthquake, there was nothing to be feared from the eruption. The following is a note which I have published in Kagoshima on the 16th immediately after my first arrival in the city:—'' (i) **Eruption.** The new craterlets are, even the nearest of them, at distances not less than 6 km from Kagoshima. The projection or precipitation of lava pieces, 70 or 80 grams in weight, is limited, even in the strong Asama-yama explosions, to the radial distances of some 4 km. Hence in the Sakura-jima outbursts, in which the individual explosions are not so powerful as those of the Asama-yama, there will be no risk in the city arising from the fall of the lava pieces of non-insignificant dimensions. (ii) **Earthquakes.** The earthquakes, so frequently occurring since the 11th, are of the volcanic nature, and, even when very strong, never attain the intensity of a great destructive earthquake, i.e., will not be able to destroy the ordinary Japanese wooden houses. Brick chimneys, stone fence-walls, etc., of unstable dimensions are, however, easily broken, and care must be paid to make them strong enough. (iii) ***Tsunami*** **(sea waves.)** Should the greater portion of the Sakura-jima be suddenly precipitated into the Bay, then there would be the production of *tsunami*. As, however, there is no prospect of the occurrence of such a convulsion, there is no need of apprehending a great *tsunami*. (iv) **Volcanic gases.** Even if the volcanic gases be strongly thrown toward Kagoshima, there is no risk of poisoning or suffocation.'' The people of Kagoshima, which city had been nearly a deserted place since the 12th, began gradually to come back on and after the 16th, while the activity of the Sakura-jima continued to be reduced steadily since the 14th of January.

As shown in § 7, the quantity of the lava outflow from the eastern craterlets group is nearly four times that from the western craterlets group, and taking together the great eruptions of 1476, 1779, and 1914, it is seen that the principal lava outflow took place on the eastern side of the line I I (Fig. 2). This fact may have some connection with the arrangement of the underground lava reservoirs.

14. *Activity along south Kyushu volcanic chain.* (Fig. 1.) In the earlier parts of the present year there have been several outbursts in succession from the south Kyushu volcanic chain, which, as Professor Jaggar remarks, proceeded from north to south. Thus, the strong explosion of the Kirishima-yama on Jan. 8th was quickly followed by the great Sakura-jima eruption of Jan. 12th. Then the Iwo-jima (or Kikaiga-shima, well known in Japanese history in connection with Shunkan Sozu, exiled to this island in 1177), situated off the south coast of Satsuma, made eruptions on Feb. 13th, accompanied by several earthquakes, one of which was of a fairly large magnitude (§ 8). Finally, the Suwanose-jima, situtated further southwards, made eruptions on March 21st. These four volcanoes, which, together with the Kaimon-dake, form a nearly straight line, are at the successive distances as follows: —

	Apprx. Distance.
Kirishima-yama to Sakura-jima	45 km.
Sakura-jima to Kaimon-dake	46

Kaimon-dake to Iwo-jima	50
Iwo-jima to Suwanose-jima	147

The above mentioned different eruptions have probably brought the volcanic activity in this part of Kyushu to an end for the time, which apparently had the effect of changing the site of volcanic outbursts again to the Fuji volcanic zone, the O-shima having made, after a quiescence of about 1½ years, very powerful lava eruptions for about 7 days between May 15th and 22nd, (1914).

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THE SAKURA-JIMA ERUPTIONS AND EARTHQUAKES. II.

[On the Sound and Ash-precipitation Areas of, and on the Level Changes caused by, the Eruptions of 1914, with Historical Sketches of Earlier Sakura-jima Outbursts.]

By

F. OMORI, Sc. D.,

Member of the Imperial Earthquake Investigation Committee.

With Plates VIII—XXXII.

CHAPTER I. NOTES ON THE TIME DISTRIBUTION OF VOLCANIC ERUPTIONS IN JAPAN.

1. List of eruptions of Kyushu and Fuji zone volcanoes. As pointed out in the Bulletin, Vol. VIII, No. 1, the remarkable connection or time relation between the great outbursts of Sakura-jima, Ōshima (Izu), Asama-yama, and Unzen-dake(1) in the memorable periods of Anei, Temmei, and Kansei, (1777 to 1792), has been repeated in the recent extraordinary activities of these same volcanoes.(2) To see, if any, the more general mutual relations, I have prepared, in Table VII, a list of all the known eruptions, from the earliest times, or the 7th century, down to 1880, relating to the Kyushu and the Fuji volcanic zones, which are approximately transverse to the general arc of the Japanese islands, radiating outwards respectively at its middle and its S.W. end. The different active mountains or islands (Fig.1) belonging to these two systems of volcanic districts are 15 in number so far as Table VII is concerned, the frequency of their eruptions being as follows:—

---

(1) *Yama, san, take,* or *dake,* means mountain. *Shima,* or *jima,* means island.

(2) It is true that the Unzen-dake (near Nagasaki) has not yet made a fresh eruption. But local earthquakes occurred recently, especially since the summer of 1915, with great frequency at the base of the mountain. According to the tromometer observations made at the Nagasaki meteorological observatory there were, between June 17th and July 20th, 1915, ninety-eight shocks whose origins were mostly in or near the Unzen-dake.

In Kyushu.		Along Fuji Volcanic Zone.	
Volcano.	Eruptions.	Volcano.	Eruptions.
Kaimon	2	Fuji	15
Tsurumi-dake	1	Asama	59
Aso	39	Ōshima (Izu)	13
Kirishima	23	Miyake-jima	11
Sakura-jima	26	Hachijo-jima	4*
Unzen-dake	3	Aoga-shima	4
Suwanose-jima	1	Kozu-shima	1
		Kita Iwo-jima	1

* (Besides 1 submarine outburst from the vicinity of Hachijo-jima.)

The conditions of activity of the different volcanoes are of course very various. Amongst the others, Kozu-shima, Tsurumi-dake, and Kaimon-dake made respectively 1, 1, and 2 eruptions during the period of about half a century, between 838 and 885. Since then, however, these three volcanoes have made no outburst at all, now for more than 1000 years. Again, Fuji made 9 eruptions in the course of 3 centuries between 781 and 1083, but remained quiet during the next 434 years, till 1517; the eruption in the latter year being followed by others in 1560, 1627, and 1700–7–8, with the average interval of 61 years. Since 1708, Fuji has remained quiet for over 200 years. On the other hand, (A), Asama, Kirishima, and Aso, and (B), Miyake-jima and Ōshima

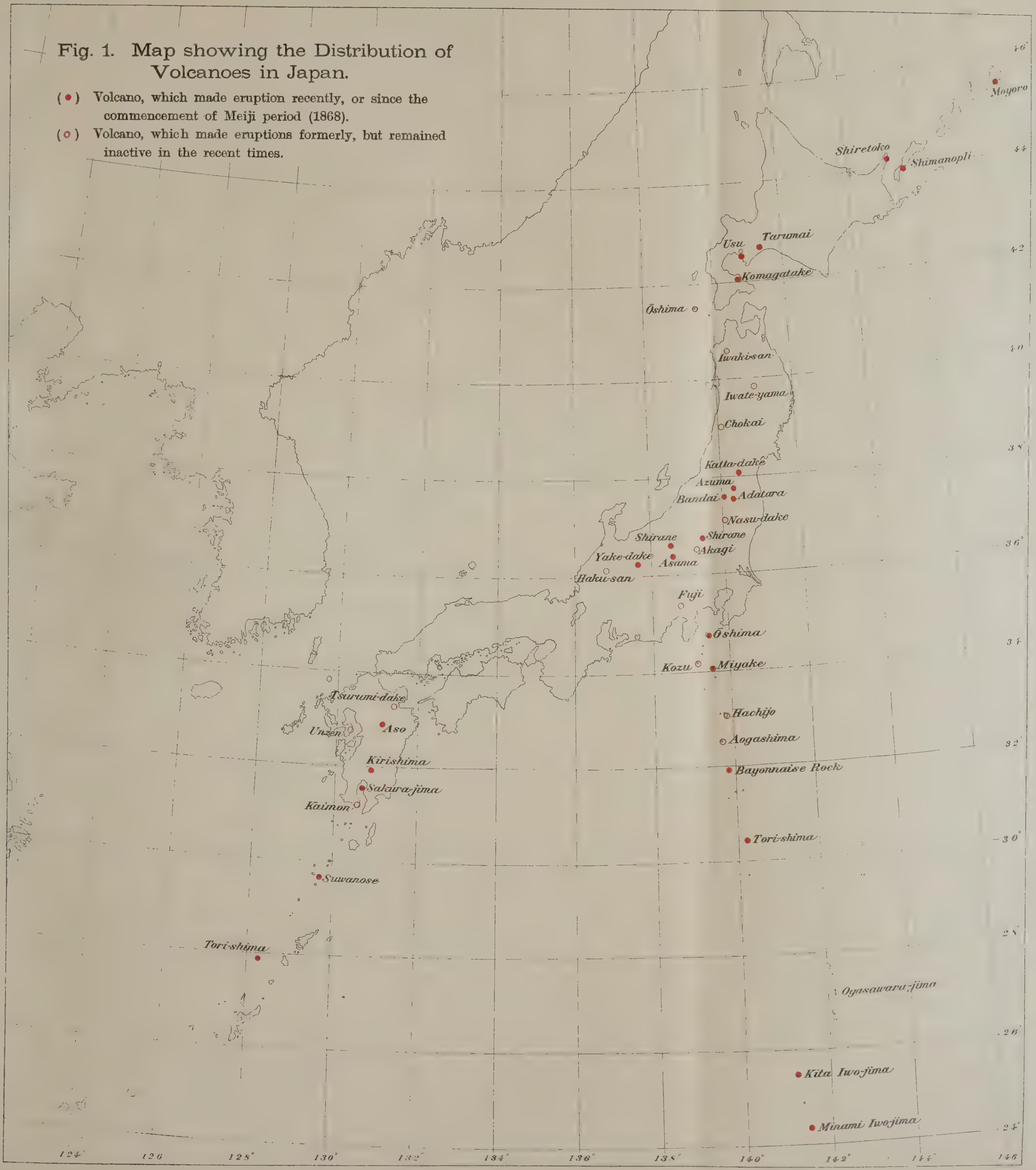

Fig. 1. Map showing the Distribution of Volcanoes in Japan.

(●) Volcano, which made eruption recently, or since the commencement of Meiji period (1868).

(○) Volcano, which made eruptions formerly, but remained inactive in the recent times.

maintained their activity unabated throughout the whole historical times. The eruptions of the (A) volcanoes, which were more generally of an explosive character, were sometimes very numerous and tended to occur in groups extending over a few years or a few decades; while those of the (B) volcanoes, which were, with a few exceptions, not explosive and consisted in the outflow of lava, occurred singly, lasting sometimes several days or weeks. The eruptions of Sakura-jima had characters of both these groups, a large lava outflow being accompanied by a considerable precipitation of pumice and ash. The eruptions of Hachijo-jima and of Aoga-shima, which were limited respectively to the intervals of 119 years between 1487 and 1606, and of 134 years between 1651 and 1785, may be regarded as secondary volcanic outbursts induced by the strong activity of Miyake-jima and Ōshima.(1)

2. Periodicity. As shown in Table I, the eruptions of Asama since the 16th century can be divided into 5 distinct groups, whose mean epochs indicate an average successive interval of 63.5 years. This is to be regarded as representing the period of recurrence of the maximum activity of the volcano.(2) The eruptions of Kirishima indicated, amongst the others, more or less definitely also the prevalence of a nearly similar period, 62.7 years in length (Table I).

---

(1) F. Omori: Report on the eruptions of Ōshima. (Japanese). Shinsai Yobo Chosakai Hokoku, No. 81.

(2) See the Bulletin, Vol. VI, No. 1.

TABLE I. ERUPTIONS OF ASAMA AND KIRISHIMA: EPOCHS OF MAXIMUM ACTIVITY.

Asama.				Kirishima.			
Year.	Number of Eruptions.	Mean Epoch.	Successive Difference.	Year.	Number of Eruptions.	Mean Epoch.	Successive Difference.
		(year.)	years.			(year.)	years.
685	1			788	1	788	
							157*
1108	1			945	1	945	
							167*
				1112	1	1112	
							63
				1167—1183	2	1175	
							60
				1235	1	1235	
							289*
				1524	1	1524	
1527—1532	3	1529					55
			70	1554—1600	8	1579	
1596—1605	4	1599					71
			55				
1644—1669	20	1654		1617—1677	4	1650	
			65				66
1704—1733	16	1719		1716—1717	2	1716	
							55
			64				
				1771—2	1	1771	
1783	(Numerous)	1783					
Mean.	—	—	63.5	Mean.	—	—	62.7

(*) Excluded in taking the mean.

The eruptions of Miyake-jima occurred, with one or two exceptions, at fairly regular successive intervals, which varied between 39 and 72 years, giving the average length of 59.3 years. The eruptions of Ōshima and Fuji since the 16th century give respectively the approximate length of 57 and 61 years. (See Table II.)

TABLE II. ERUPTIONS OF MIYAKE-JIMA, ŌSHIMA, AND FUJI: SUCCESSIVE TIME INTERVALS.

Miyake-jima.		Ōshima.		Fuji.	
Year, Month of Eruption.	Successive Difference.	Year, Month of Eruption.	Successive Difference.	Year, Month of Eruption.	Successive Difference.
	years.		years.		years.
July 886(?)					
	198(?)*			1083	
1085					
	69	1112			
1154					
			304*		
	316*	Sept. 1416			
Dec. 1469					
	65			1517	
Mar. 1535					
					43
	61		267*	1560	
Nov. 1595					
					67
	47			1627	
Mar. 1643					
					73
	69	1684			
Feb. 1712				1700	
	52		93	Dec. 1707	
Aug. 1763				1708	
	72	1777			
			45		
Jan. 1811(1)		1832			
Nov. 1835					
	39		55		
July 1874					
		Dec. 1876(2)			
			36		
		Mar. 1912(2)			
Mean.	**59.3**	Mean.	**57**	Mean.	**61**

(*) Excluded in taking the mean.

(1) The Miyake-jima eruption of 1811 consisted simply in detonations, earthquakes, and some slight explosive action, being much inferior in magnitude to the others which were attended by lava outflows. It is, therefore, here provisionally excluded in taking the successive intervals.

(2) Commencement of prolonged eruptive period.

Collecting together the results relating to the mean epochs of group explosions of Asama and Kirishima and the single eruptions of Miyake-jima, Ōshima, and Fuji, we see that the period of recurrence of volcanic activity varied between 57 and 63.5 years, giving the average value of 61 years, as follows:

Average difference between successive mean, or most active, epochs:—

	years.
Asama,	63.5
Kirishima,	62.7
Average difference between successive single eruptions:—	
Miyake-jima	59.3
Ōshima,	57.0
Fuji,	61.0
Mean,	61.1 years.

This periodicity gives a certain parallelism among the time distribution of the eruptions of the different volcanoes in question. (See Table III.) Thus the Fuji eruptions of 1517, 1560, 1627, and 1700, were each followed after a mean interval of 16 years by an epoch of maximum activity of Kirishima, then after a further mean interval of 9 years, by that of Asama; the eruption of Miyake-jima also invariably occurring in the later portion of each series. After 1700–8, Fuji became quiet, but the other three volcanoes made each an eruption between 1763 and 1783.

Beside the period of 61 years here deduced, there must exist a great many others of different lengths in the time distribution of volcanic eruptions.

TABLE III. PARALLELISM IN THE SUCCESSIVE OCCURRENCES OF ERUPTIONS OF FUJI, KIRISHIMA, ASAMA, AND MIYAKE-JIMA.

Single Eruption.	Mean, or Most Active, Epoch.		Single Eruption.
Fuji.	Kirishima.	Asama.	Miyake-jima
1517 (year.)	1524 (year.)	1529 (year.)	1535 (year.)
1560	1579	1599	1595

Single Eruption.	Mean, or Most Active, Epoch.		Single Eruption.
Fuji.	Kirishima.	Asama.	Miyake-jima.
1627 (year.)	1650 (year.)	1654 (year.)	1643 (year.)
1700	1716	1719	1712
—	1771	1783	1763

3. Alternations in eruptions of different volcanoes. In Tabl IV is given a comparative list of the years of eruption of Asama, Aso, Kirishima, and Fuji, grouped with reference to the activity of the first named volcano. It will be observed that the eruption of Asama occurred, on the whole, in alternation to those of Aso and Kirishima. Thus, during the six intervals of 1109–1526, 1533–95, 1606–43, 1670–1703, 1755–75, and 1816–65, Asama made no eruption at all, while Aso and Kirishima made together respectively 18, 14, 5, 4, 3, and 5 eruptions. On the other hand, during the five intervals of 1527–32, 1596–1605, 1644–61, 1704–55, and 1776–1803, Asama made respectively 3, 4, 19, 18, and 7 eruptions, while Aso and Kirishima made no outburst at all or only 1 or 2 eruptions. Between Aso and Kirishima, however, there is again an almost perfect alternation in the occurrences of their eruptions. At the same time, it is to be noted that the epochs of activity of Asama were each followed and preceded at a close interval by those of Kirishima and Aso. The activity of Mount Fuji took place nearer the eruptions of the two latter than those of Asama. (See also Table IV.)

Table V is a similar list relating to Sakura-jima, Kaimon, Unzen, Ōshima, Miyake-jima, Hachijo-jima, Aoga-shima, etc., classified according to the activity of the first named volcano. The alternate occurrences of the eruptions of Ōshima and Miyake-jima are very clearly indicated. (See also § 2.) On the whole, however, either of these two volcanoes was in activity in the eruptive epochs of Sakura-jima. Again, the eruptions of Unzen, which took place only in 1657, 1663, and 1792, followed those of Sakura-jima in 1642 and 1779.

TABLE IV. COMPARATIVE LIST OF THE YEARS OF ERUPTION OF FUJI, ASAMA, ASO, AND KIRISHIMA.

*....Stronger outburst.

The figure within brackets is the number of eruptions during the time interval concerned.

Fuji.	Asama.	Aso.	Kirishima.
	685*		
781 800 826 864 870 937 999 1033 1083		864 867	742(?) 788 945
	1108*		
			1112 1167 1183 1235
1517		1238–1388 (9) 1434 1473 1506 1522	
			1524
	1527 1528 1532		
		1533 1542	
1560			1554–5
		1562 1564	
			1566 1574 1576-8
		1582 1584	
			1585 1587 1588
		1592	
	1596 1596 1598 1605	1598	1598–1600

TABLE IV. (*Cont.*)

Fuji.	Asama.	Aso.	Kirishima.
		1612	
1627			1617–8
		1631 1637	
	1644–1661 (19)	1649	1659-61
			1662-4
		1668	
	1669		
		1675	
			1677
		1683 1691	
1700 1707* 1708	1704 1706 1709–1733 (14) 1754 (2)		1716–17*
		1764 1765*	
			1771–2
	1776 1777 1783* 1785 1803 (3)		
		1806	
	1815		
		1826–1830 (4) 1854	
	1866 1869		
		1874	
	1875 1879		

TABLE V. COMPARATIVE LIST OF THE YEARS OF ERUPTION OF SAKURA-JIMA, ŌSHIMA, MIYAKE-JIMA, UNZEN, ETC.

*....Stronger Outburst.

Sakura-jima.	Kaimon, Unzen, etc.	Ōshima.	Miyake-jima.	Hachijō-jima, Aoga-shima, etc.
	764*(Subm., near Kokubu) 867*(Tsurumi-dake)	680 (Ōshima ?) 856 (Ōshima ?)		838*(Kozu-shima.)
	874*(Kaimon) 885*(")			
			886* (Miyake-j. or vicinity) 1085	
		1112*		
			1115	
		1416 1421		
1468 1471* 1473 1475* 1476*			1469	
1642	1657 (Unzen) 1663 (")		1535 1595 1643	1487 (Hachijō.) 1518 (") 1605 (") 1606 (Subm., near Hachijō.) 1652 (Aoga-shima)
1678		1684 1684		
1706			1712	
1742 1749 1756 1767			1763	

Sakura-jima.	Kaimon, Unzen, etc.	Ōshima.	Miyake-jima.	Hachijō-jima, Aoga-shima, etc.
1779* 1780–99 (10 erups.)	1792* (Unzen)	1777* 1778* 1778* 1789 1803		1780* (Aoga-shima) 1781 (,,) 1783 (,,) 1785* (,,)
1860(?)	1813 (Suwanose)		1811	
		1822		
			1835	
		1870		
			1874	
		1876		1880 (Kita Iwō-jima.)
1914* (Jan.)		1912* 1912* 1914* (May)		

4. List of recent volcanic eruptions in Japan. Table VIII gives a list of the yearly number of eruptions in different parts of Japan during the 35 years since 1880, relating to 25 volcanoes (fig. 1), as follows :—

TABLE VI. NUMBER OF RECENT VOLCANIC ERUPTIONS IN JAPAN.

District.	Volcano.	Number of Eruptions.
(i). Northern part of Honshu (Main Island).	Bandai-san.	1*
	Adatara-san.	5
	Azuma-san (Issaikyo).	8
	Katta-dake (Zoo-dake).	4
(ii). Central part of Honshu (Main Island).	Asama-yama.	177*
	Yake-dake.	43*
	Shirane-san (near Kusatsu).	8
	Shirane-san (near Nikko).	1

TABLE VI. (*Cont.*)

District.	Volcano.	Number of Eruptions.
(iii). Islands of Fuji Volcanic Chain.	Ōshima (Izu).	5*
	Tori-shima.	1
	Submarine Eruption (near North Iwo-jimā).	1
	,, (,, South Iwo-jima).	2*
	,, (,, Bayonnaise Rock).	3
(iv). Hokkaido and Kurile Islands.	Tarumai-san.	5*
	Komaga-take.	2
	Usu-san.	1*(1)
	Shiretoko (in Kitami).	2
	Shimanopli (in Kunashiri-jima).	1
	Moyoro (in Etrup-jima).	1
	Shinshiri-jima.	1
(v). Kyushu and Lyukyu.	Aso-san.	11
	Kirishima-yama.	27
	Sakura-jima.	1*(1)
	Suwanose-jima.	5*
	Tori-shimā (Lyukyu).	1

*....Including one or more large eruptions. (1)....Group.

Of the different volcanoes tabulated above, Asama, Kirishima, and Aso made within the time limits under consideration very frequent outbursts, none of which were, however, of a gigantic magnitude. Of these three mountains, Kirishima broke into eruptions, on the whole, in alternation to those of Asama and Aso. (See also § 2.) On the other hand, the four volcanoes of Bandai-san, Ōshima, Usu, and Sakura-jima, each of which renews the activity after long intervals of relative rest, made very powerful eruptions during the interval since 1880.

The regional connection in the eruptions of the volcanoes belonging to the different groups is clearly indicated in Table VII. Thus, the 4 volcanoes of Group (i), situated close to each other in the boundary districts of the two provinces of Iwashiro and Rikuzen, made altogether 18 outbursts, which were limited to the 13 years between 1888 and 1900. Then followed the marked activity of the southern portion of the Fuji volcanic chain, namely, of the islands stretching from the coast of Izu to the Volcano Islands group; the explosion of Tori-shima in 1902 having been followed, during the 12 years between 1904 and 1915, by the lava eruptions of Ōshima and the submarine outbursts near the Bayonnaise Rock and the North and South Iwo-jima's. Simultaneously, the northern portion of the Fuji chain expressed its activity in the numerous volcanic explosions of Asama and Yake-dake, respectively since 1899 and 1907; there being also between 1905 and 1910 the eruptions of the three volcanoes of Komaga-take, Tarumai-san, and Usu-san, situated on, or close to, the coast of Volcano Bay, in Hokkaido.

On the whole, it may be said that the great lava eruption of Suwanose-jima in 1884 and the tremendous explosion of Bandai-san in 1888 were followed by an epoch of comparative rest for the 15 years, between 1889 and 1903, during which the volcanic outbursts were weak and not very numerous. Since 1904, however, the eruptive manifestations were greatly increased, both in intensity and in number, culminating in the epoch of 6 years between 1909 and 1914, during which interval there were altogether 194 eruptions from 11 different volcanoes. It was in 1914, when 7 volcanoes were in activity, that Sakura-jima made the last great eruption.

TABLE VII. LIST OF THE YEARS OF ERUPTION OF THE KYUSHU AND THE FUJI CHAIN VOLCANOES.

*....Large Eruption.

Fuji.	Asama.	Aso.	Kiri-shima.	Sakura-jima.	Kaimon, Unzen, Suwanose, etc.	Ōshima.	Miyake-jima.	Hachijō-j., Aoga-shima, etc.
						680(?)		
	685*							
			742(?)					
					764* [Subm. erupt. near Kokubu.]			
781								
			788					
800*								
826								838* [Kōzu-shima.]
						856(?)		
864*		864						
		867			867 [Tsurumi-d.]			
870								
					874* [Kaimon.]			
					885* [Kaimon.]			
937							886(?)	
999			945					
1033								
1083							1085	
	1108*							
			1112			1112*		
							1154	
			1167					
			1183					
			1235					
		1238						
		1269						
		1271						
		1274						
		1333						
		1335						
		1340						
		1375						
		1388						
						1416		
						1421		
		1434						
				1468			1469	
				1471*				

Fuji.	Asama.	Aso.	Kiri-shima.	Sakura-jima.	Kaimon, Unzen, Suwanose, etc.	Ōshima.	Miyake-jima.	Hachijō-j., Aoga-shima, etc.
		1473 (May)		1473 (May)				
				1475*				
				1476*				
								1487 [Hachijō.]
		1506						
1517								
								1518 [Hachijō.]
		1522						
			1524					
	1527							
	1528							
	1532							
		1533						
							1535	
		1542						
			1554–5					
1560								
		1562						
		1564						
			1566					
			1574					
			1576–8					
		1582						
		1584						
			1585					
			1587					
			1588					
		1592						
							1595	
	1596 (May)							
	1596 (Aug.)							
	1598	1598	1598–1600					
	1605							1605 [Hachijō.]
								1606 [Subm. erupt. near Hachijō.]
		1612						
			1617–8					
1627								
		1631						
		1637						
				1642			1643	

Fuji.	Asama.	Aso.	Kiri-shima.	Sakura-jima.	Kaimon, Unzen, Suwanose, etc.	Ōshima.	Miyake-jima.	Hachijō-j., Aoga-shima, etc.
	1644							
	1645 (Feb.)							
	1645 (May)							
	1647 (Feb.)							
	1647 (Mar.)							
	1648 (Mar.)							
	1648 (Aug.)							
	1649 (Aug.)	1649						
	1651							
	1652							1652 [Aoga-shima.]
	1655							
	1656							
	1657				1657 [Unzen.]			
	1658							
	1659		1659–61					
	1660							
	1661 (Apr.)							
	1661 (Apr.)							
	1661 (Oct.)							
			1662–4					
					1663 [Unzen.]			
		1668						
	1669							
		1675						
			1677	1678				
		1683				1684 (Mar.)		
						1684 (Apr.)		
		1691						
1700								
	1704							
	1706			1706				
1707*								
1708								

Fuji.	Asama.	Aso.	Kiri-shima.	Sakura-jima.	Kaimon, Unzen, Suwanose, etc.	Ōshima.	Miyake-jima.	Hachijo-j., Aoga-shima, etc.
	1709							
	1710							
	1711		1716				1712	
	1717		1717*					
	1718							
	1720							
	1721							
	1722							
	1723 (Feb.)							
	1723(Aug.)							
	1728							
	1729							
	1732							
	1733							
				1742				
				1749				
	1754(Aug.)							
	1754(Aug.)							
				1756				
							1763	
		1764						
		1765*						
				1766(June)				
				1766(July)				
			1771–2					
	1776							
	1777					1777*		
						1778*(Apr.)		
						1778*(Dec.)		
				1779*				
				1780(Sept.)				
				1780 (Oct.)				1780(1)
				1781(Apr.)				
				1781(May)				1781(1)
				1782				
	1783*			1783				1783(1)
	1785			1785				1785*(1)

(1) Aoga shima.

Fuji.	Asama.	Aso.	Kiri-shima.	Sakura-jima.	Kaimon, Unzen, Suwanose, etc.	Ōshima.	Miyake-jima.	Hachijo-j., Aoga-shima, etc.
						1789		
				1790				
				1791				
					1792* [Unzen.]			
				1799				
	1803 (July)							
	1803(Nov.)							
	1803(Nov.)							
						1803		
		1806						
							1811	
					1813 [Suwanose]			
	1815							
						1822		
		1826						
		1827						
		1828						
		1830						
							1835	
		1854						
				1860(?)				
	1866							
	1869							
						1870		
		1874					1874	
	1875							
						1876		
	1879							
								1880 [Subm. near Kita-Iwojima.]

—1915.

Group.	shu and Lyukyu.			Total Number of	
Volcano. / Year.	Suwanose-jima.	Sakura-jima.	Tori-shima.	Eruptions.	Volcanoes.
1880				2	2
1881				—	—
1882				2	2
1883				1	1
1884	**1**			2	2
1885	0			1	1
1886	1			1	1
1887				1	1
1888				4	3
1889	1			5	5
1890				2	2
1891				2	1
1892				—	—
1893				3	1
1894				17	5
1895				8	3
1896				3	1
1897				4	4
1898				3	1
1899				10	3
1900				12	4
1901				6	1
1902				4	3
1903			1	4	3
1904				2	2
1905				2	2
1906				3	3
1907				6	2
1908				8	3
1909				19	3
1910				15	5
1911				57	2
1912				21	4
1913				48	3
1914	1	**1**		34	7
1915	1			5	4

TABLE VIII. LIST OF YEARLY NUMBER OF RECENT VOLCANIC ERUPTIONS IN JAPAN, 1880–1915.

(Gothic numeral indicates large eruption.)

Group.	(i). N. Part of Honshu.				(ii). Central Part of Honshu.				(iii). Fuji Zone Islands.				(iv). Hokkaido and Kurile Islands.					(v). Kyushu and Lyukyu.					Total Number of	
Vol-cano. / Year.	Bandai.	Azuma.	Adatara.	Katta.	Shirane. (Near Kusatsu).	Shirane. (Near Nikko.)	Asama.	Yake-dake.	Tori-shima.	Vicinity of Kita and Minami Iwo-jima.	Vicinity of Bayonnaise Rock.	Ōshima.	Tarumai.	Komaga-take.	Usu.	Shiretoko.	Kurile Islands.	Aso.	Kirishima.	Suwanose-jima.	Sakura-jima.	Tori-shima.	Eruptions.	Volcanoes.
1880					1					1			1				1						2	2
1881																							—	—
1882																							2	2
1883																	1						1	1
1884																		1		**1**			2	2
1885													1							0			1	1
1886													0							1			1	1
1887													1										1	1
1888	**1**													1					2				4	3
1889						1	1									1			1	1			5	5
1890					1											1			0				2	2
1891																			2				2	1
1892																							—	—
1893		3																					3	1
1894		3					6						1					5	2				17	5
1895		2		3															3				8	3
1896				0															3				3	1
1897				1	1													1	1				4	4
1898																			3				3	1
1899			2				4												4				10	3
1900			3		1		7												1				12	4
1901					0		6																6	1
1902					2		1		1														4	3
1903					1		0												2			1	4	3
1904					0		1			**1**													2	2
1905					1		0							1									2	2
1906							1				1							1					3	3
1907							3	3										0					6	2
1908							5	2										1					8	3
1909							9	9					**1**					0					19	3
1910							10	2				1			**1**			1					15	5
1911							40	17				0						0					57	2
1912							10	8				**2**						1					21	4
1913							45	1				0							2				48	3
1914							28	0		**1**		**1**					1		1	1	**1**		34	7
1915							0	1		0	2	1					0		0	1			5	4

Errata.

Table VIII, p. p. 53–54. The yearly frequencies of eruptions of Shirane (near Kusatsu) and Tarumai and the figures in the two right-hand side columns of the table for the interval of 1880 to 1883 are to be corrected as follows:—

Year.	(ii) Shirane (near Kusatsu).	(iv) Tarumai.	Total Number of	
			Eruptions.	Volcanoes.
1880			2	2
1881			—	—
1882	1		1	1
1883		1	2	2

CHAPTER II. HISTORICAL ACCOUNTS OF SAKURA-JIMA ERUPTIONS.

5. Submarine eruptions in Kagoshima Bay. The island of Sakura-jima is only 42 km distant from the great volcanic masses of Kirishima. The existence of a deep sea area, namely, the northern portion of Kagoshima Bay, between these two mountains, is certainly a remarkable geographical feature, and it is not surprising that there were submarine eruptions and formations of new islands on more than one occasions in our historical times.

The earliest known volcanic disturbance in Kagoshima Bay is that of Dec. 764, which is recorded in "Zoku-Nihonki" (續日本紀), one of the old national histories, as follows:—"Sounds like thunders were heard towards the west, when, at the boundary of the two provinces of Ōsumi and Satsuma, the air was rendered dark by smokes and clouds, from which lightnings flashed out. The sky cleared after seven days, and it was then found out that in the sea off Shinni-mura (信爾村) of Kagoshima, sand and rock collected themselves into three new islets. These latter, exposing to view fires and vapours, like the furnace of a smith, were continuous and looked like a straight-ridged garden-house (四阿之屋). 62 houses were buried under the islets, with the loss of more than 80 lives." The new islets, called Kamizūkuri-jima ("Islands created by gods") or Ōnamochi-jima (Island of Ōnamochi), seems to have been shaken by earthquakes for the several succeeding years, as, in July 766, the government sent relief among the distressed people. 13 years later on, or in Jan. 779, there was established the temple of Ōnamochi on one of the new islets, probably because, by that time, the seismic and volcanic disturbances had already completely ceased. The name of Kagoshima used in former times to be applied to the extensive tract at the boundary of the two provinces of Satsuma and Ōsumi, and the village of Shinni-mura mentioned in the old record is probably identical with the present Shikine-mura* on the north-east coast of Kagoshima Bay, not far from the town of Kokubu. Thus, the above mentioned eruption very likely relates, not to Sakura-jima, but to a submarine volcanic outburst close to the coast of the last named place, where still exist two rocky islets known as Heta-kojima and Oko-jima; the third, whereon formerly stood the temple of Ōnamochi (now removed to the vicinity of Kokubu), having, by the subsequent subsidence, again disappeared under the water. The site is still known as the Miyanosu ("Temple shoal"), its present depth being 21 fathoms. (See fig. 3.) Fig. 6, Pl. XII, is a view of the Kamizukuri-jima taken in Sept. 1914 from the vicinity of Hamanoichi at the northern coast of Kagoshima Bay.

6. Extinct craters of Sakura-jima. The three principal peaks of Kita-dake, Naka-dake, and Minami-dake arranged in the direction of N. slightly W. and S. slightly E., form the top ridge of Sakura-jima, whose length is about 1.7 km and whose average elevation is some 1050 m above sea-level. Of these three peaks, the crater of Naka-dake is the oldest, and that of Kita-dake the next oldest, both being completely extinct. The southern peak, Minami-dake, is of a newer date than the other two and has a number of fumaroles emanating from near the summit. The Minami-dake crater, although it gave no lava outflow in the historical times, is still active in a sense, as in the great eruptions of the periods of

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* In the Satsuma dialect "Shikine" is pronounced in a short contracted manner, somewhat like "Shinne."

Anei (1779) and of Taisho (1914), it served as the mouth of the premonitory outburst, whereby a black smoke column was shot vertically to a great height.

The crater at the top of *Kita-dake*, or North Peak, is a nice regular depression, 400 to 470 m in diameter, which, being a good deal filled up, looks quite shallow. The rim is composed of three detached rocky remnants, whose maximum height before the eruption was 1133.5 m, but whose heights after the eruption were from 1110 to 1118 m above sea-level; the height reduction being mainly, if not entirely, due to the strong earthquake shocks which broke down to a more or less extent the cliffs at and near the top portions of the island. The level of the crater bottom before the eruption indicated in the Military Survey map was 1037 m. There is no fumarole on Kita-dake, which, in fact, gives no sign of activity.

The crater of *Naka-dake*, or Middle Peak, which is slightly lower than Kita-dake, is almost entirely filled up, and forms a very shallow basin, about 340 m in N.S. and 150 to 200 m in E.W. direction; the S. rim, which forms at the same time the N. cliff of Minami-dake, having the height of 1070 m.

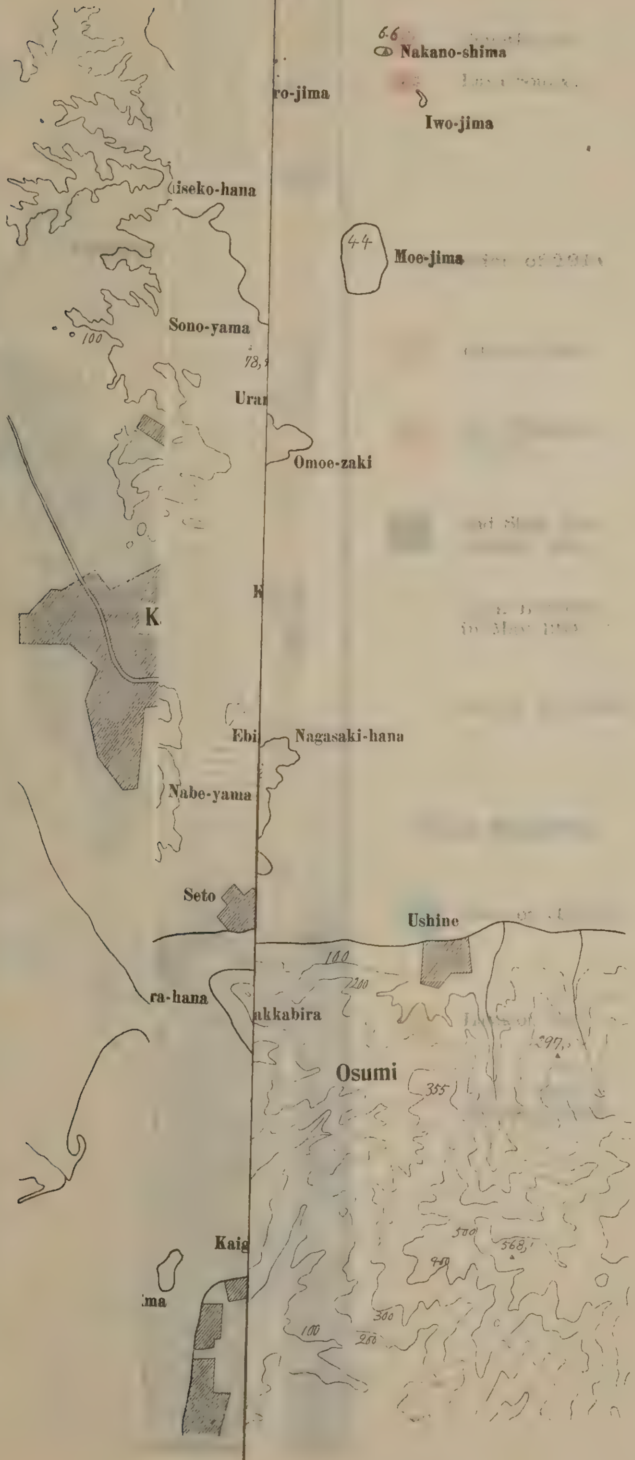
The crater of *Minami-dake*, or South Peak, which is contiguous to that of Naka-dake, is much greater than the two others, and have the diameter length of about 640 m in N.S. and 500 m in E.W. direction, with the depth of about 250 m. When visited on April 24th, 1915, fumes were being given out feebly from the W. and N.E. parts of the inside of the crater, as well as from the outside slope, near the top, at the E. and S. sides. The crater of Minami-dake presents a sight much grander than that of Asama-yama, and has very precipitous inside cliffs; the ridge of the surrounding wall being at places very thin as to barely afford a footing for us to stand on.

The lava outflows in the Bummei period (1468–1476) and subsequent eruptions took place all from side craterlets situated at heights less than 750 m above sea-level.

Nabe-yama and Ebinotsuka. Nabe-yama, so called from its resemblance to an inverted Japanese cooking pot, is a low but highly characteristic parasitic cone, situated 3.0 km to the E. slightly S. of Minami-dake, and a horse-shoe in form, with an opening at the E. side. The N.S. diameter of the flat top ridge is about 900 m and that of the base about 1600 m, the highest point, situated at the W. side, being 358 m above sea-level. Ebinotsuka is a much smaller but similar cone, 122 m in height, which is situated 4.0 km to the due E. of Minami-dake. Although made up entirely of ash and pumice, these two hills have preserved their form perfectly and consequently must have been formed at no very distant epochs. In fact, according to the writings on the Anei eruption (1779) by Ijichi Kiken, of Tarumizu, the Nabe-yama crater is ascribed to the eruption of the 3rd year of the Bummei period, namely, 1471, a supposition which is by no means improbable. The explosion craterlets and lava sources of the eruptions in the Bummei and Anei periods, whose positions are indicated in fig. 2, will be described more in detail in No. 3, of this Volume.

7. Number of Sakura-jima eruptions. The authentic record of the eruptions of Sakura-jima goes back to 1468. Since then there were in the course of 4½ centuries altogether 26 eruptions or groups of eruptions of the volcano, whose dates, both Japanese and European, are given in Table IX. In the following §§ I give accounts of the strong Sakura-jima eruptions in the two periods of Bummei (1468–1476) and Anei (1779).

8. Eruptions in Bummei period, 1468–1476. This series of the voleral



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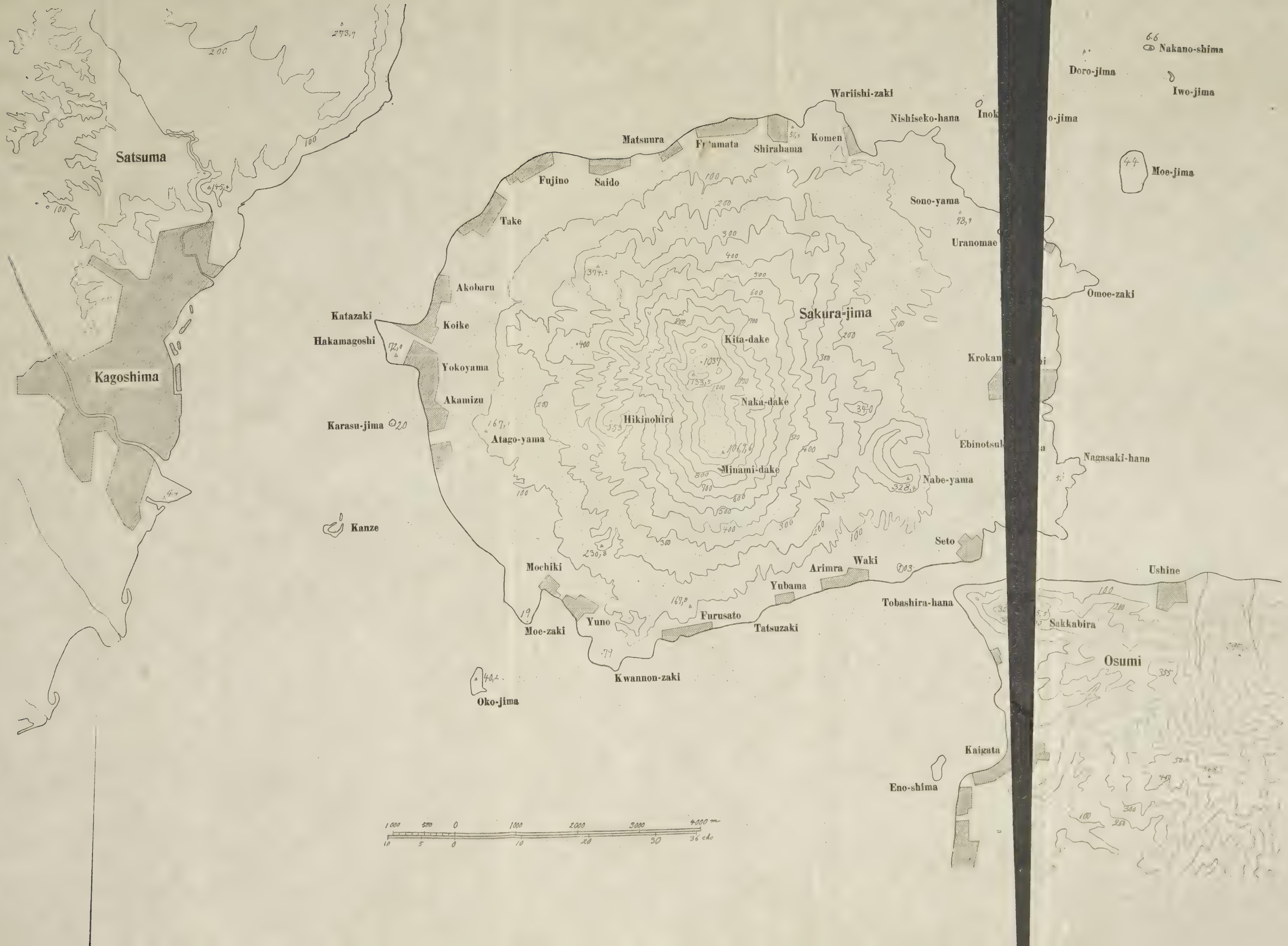
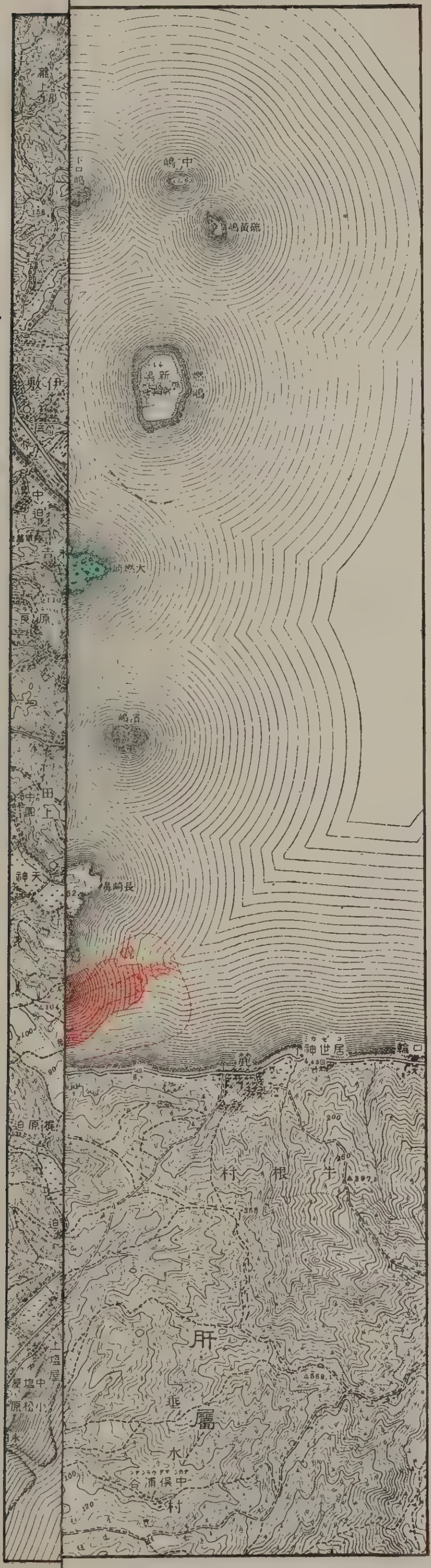
Sakura-jima before the Eruption of 1914: Map showing the general contour and the position of different villages.



Chain of Kirishima,

ption of 1914.

Pl. IX.



● Craterlet, or
● Lava Source.

Eruption of 1914.

🟥 Lava of 1914.

▤ *Do.*, Submerged Portion.

▨ 2nd Stage Lava Outflow, 1915.

- - - Lava Boundary in May 1914.

Do., in Dec. 1914.

Older Eruptions.

🟩 Lava of 1468-76.

🟨 Lava of 1779.

⌒ Crater Wall, or Eruption Canal.

Fig. 2. Map of Sakura-jima, showing the Distribution of the Lava Outflows and Craterlets of the Three Great Eruptions of Bummei (1468-1476), Anei (1779), and Taisho (1914) Periods.

I I. . . .Direction of the Volcanic Chain of Kirishima, Sakura-jima, Kaimon, etc.
II II. . . .Fracture Line of the Eruption of 1914.

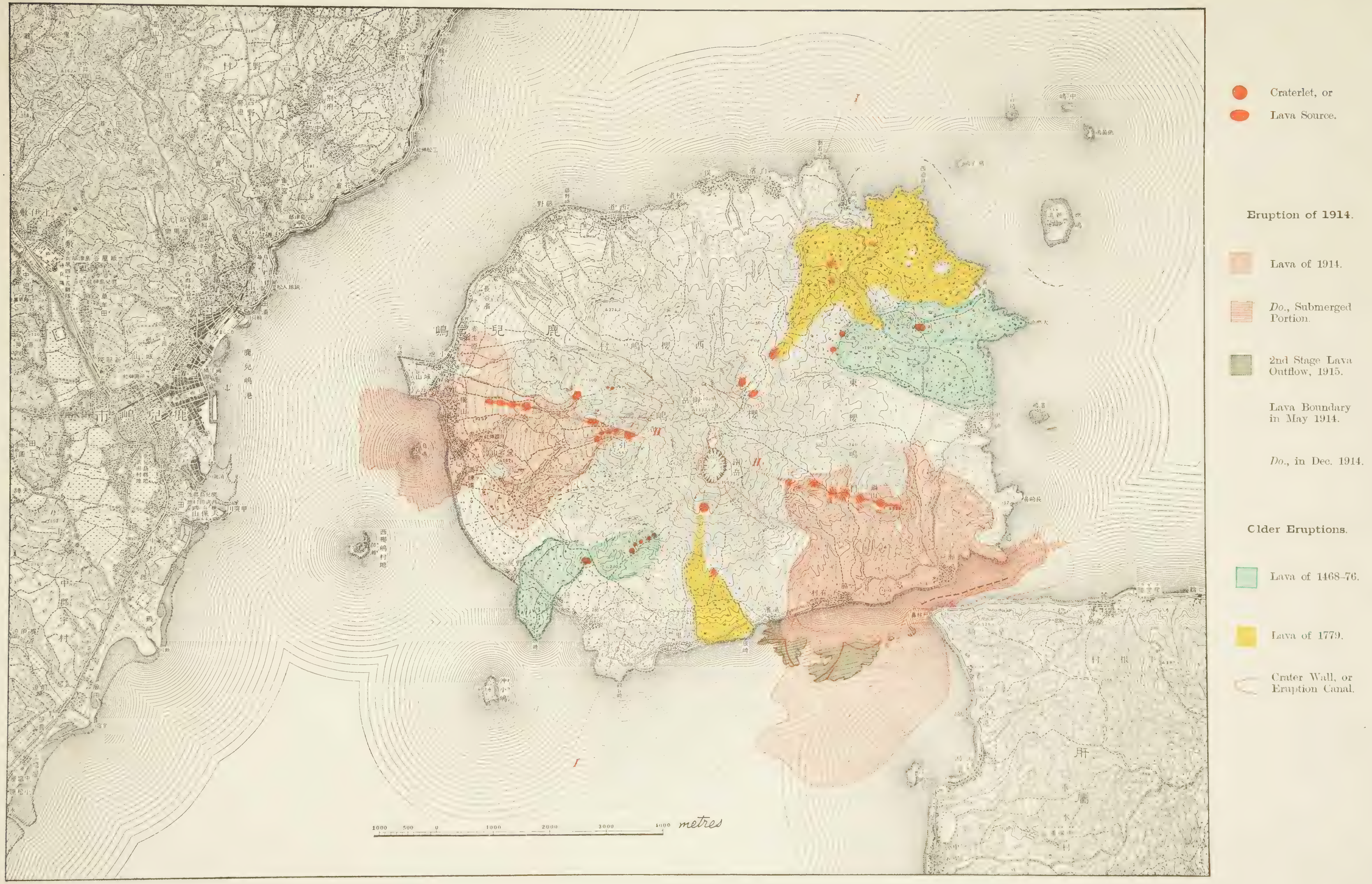
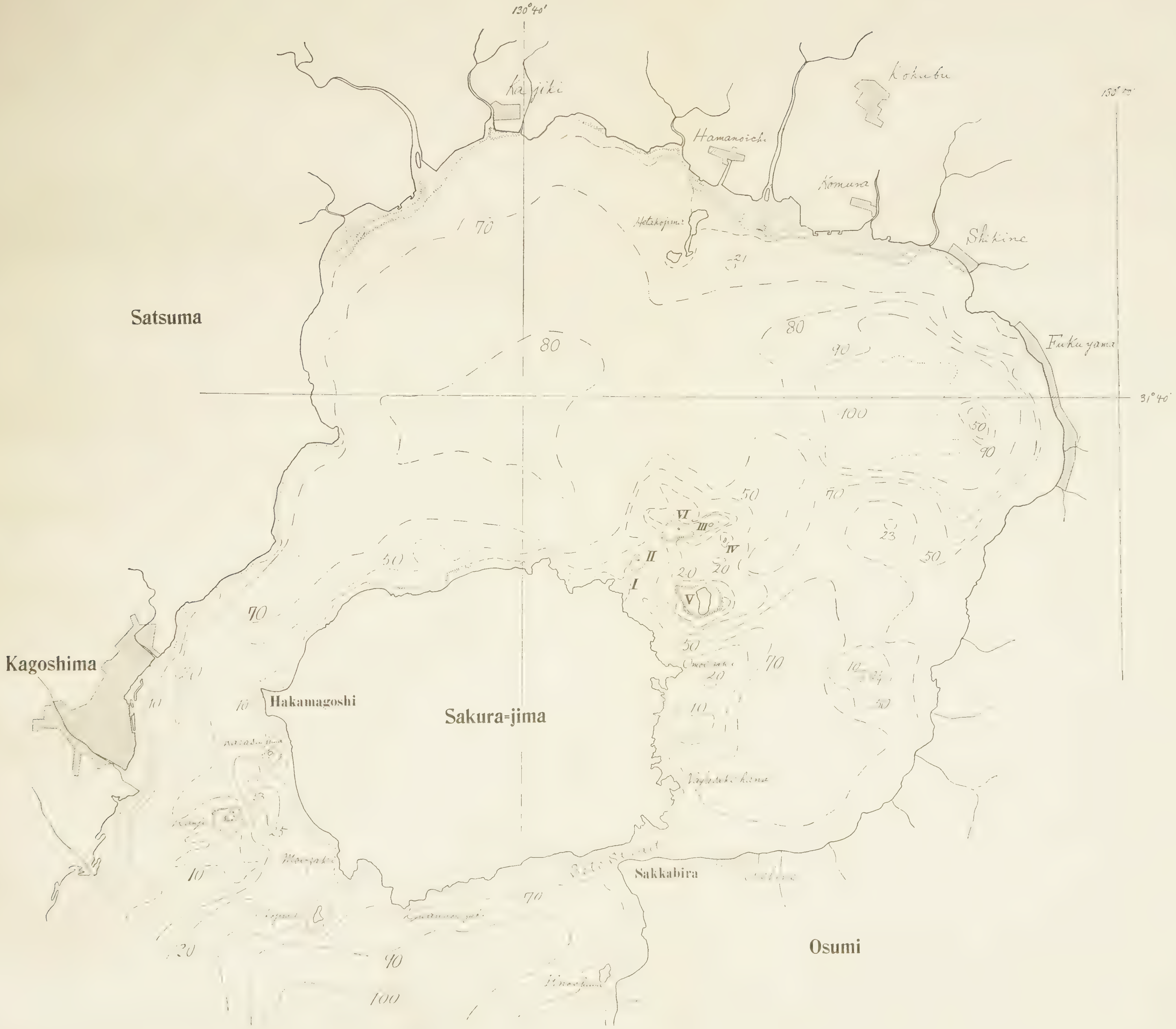


Fig. 3. Chart of the Northern Portion of Kagoshima Bay before the Sakura-jima Eruption of 1914.

The depth is indicated in fathoms.



canic outbursts began with a small explosion in 1468. 3 years later, on Nov. 3rd, 1471, a strong eruption took place on the E. side, above Krokami, and threw out ash, sand, and burning stones, the lava outflow forming the cape of Ōmoe-zaki. It is recorded that in this case the burning stones accumulated into a rocky hill, which may possibly refer to the lava-source of Ōmoe-zaki or the parasitic cone of Nabe-yama. Then, the eruption of Sept. 24th, 1475, took place on the S.W. side of Sakura-jima, from the vicinity of Nojiri-mura, causing outflows of lava. The eruption on Oct. 8th of the next year was preceded by strong earthquakes, which had began from the 3rd of the same month and was very active during about 1 week; the lava, which flowed out on this occasion, forming the cape of Moe-zaki at the S.W. end of Sakura-jima. (See fig. 2.)

Fig. 5, (Pl. XII), is the view of Moe-zaki, photographed in Sept. 1915. The lava flow of the Bummei period remains, after the lapse of 440 years, still in a fresh state, being covered principally by slender pine trees.

9. Eruptions in Anei period, 1779. The eruption of the 8th year of Anei took place in a fine and quiet weather. The local earthquakes, which constituted the precursory disturbances of the volcanic outburst, were composed of very sharp movements of short duration, often quite strong in intensity. These began to occur in the island already from about 6 p.m. on Nov. 8th (lunar calendar, Sept. 29th), the festival day of the Gosha-Daimyojin, of Akamizu, the principal temple in the island, with a high frequency of 30 to 40 in one hour, not decreasing in activity even after the noon of the next day, the 9th (lunar calendar, Oct. 1st). On the morning of the latter day, the colour of the sea water became purple, while the well waters at the beaches bubbled up and flowed out copiously in small streamlets. In the city of Kagoshima, earthquakes were incessantly felt since 8 or 9 p.m., on Nov. 8th, till the next day, at about 11 a.m., thin white smokes were vertically projected from the Shiramizu (" White pond "), or the crater at the top, of Minami-dake. This was the opening step in the process of the eruption, and was followed at about 2 p.m. by a tremendous outburst from a place termed Moeno-kashira (" Source of burning ") at the S. flank of Minami-dake and above the village of Furusato. The detonation of the explosion was excessively loud, and the column of dense gray and black smokes, like masses of cotton, which gave out innumerable flashes of lightning, ascended vertically, pierced through layers of clouds, and reached a height of 3 *ri* 2 *cho* 16 *ken**, or 12,030 metres, thence, spreading out in the form of an open umbrella, was gradually carried eastwards. (See fig. 11.) From the town of Tarumizu (province of Ōsumi), situated at a distance of 8 km to the S.E. from the scene of eruption, could be distinctly observed with naked eye the lava fragments which were projected out from among the smokes like groups of flying birds, causing at once conflagrations of the houses or plants they fell on. After a time, the smokes spread over the city and caused the precipitation of ash, followed by that of sand, rendering the air completely dark, while the earthquakes and thunders became more and more intensified. At the first strong outbreak, the inhabitants of Kagoshima, which suffered no direct damage from the eruption or the earthquakes, were seized by panic, in consequence of the imagined dangers from the rushing of gigantic *tsunamis*, an enormous accumulation of burning stones and ashes, etc. Thereupon, by order from the feudal

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* According to the estimation made at the Meiji-kwan (old astronomical observatory) in the city of Kagoshima.

Pl. XI.

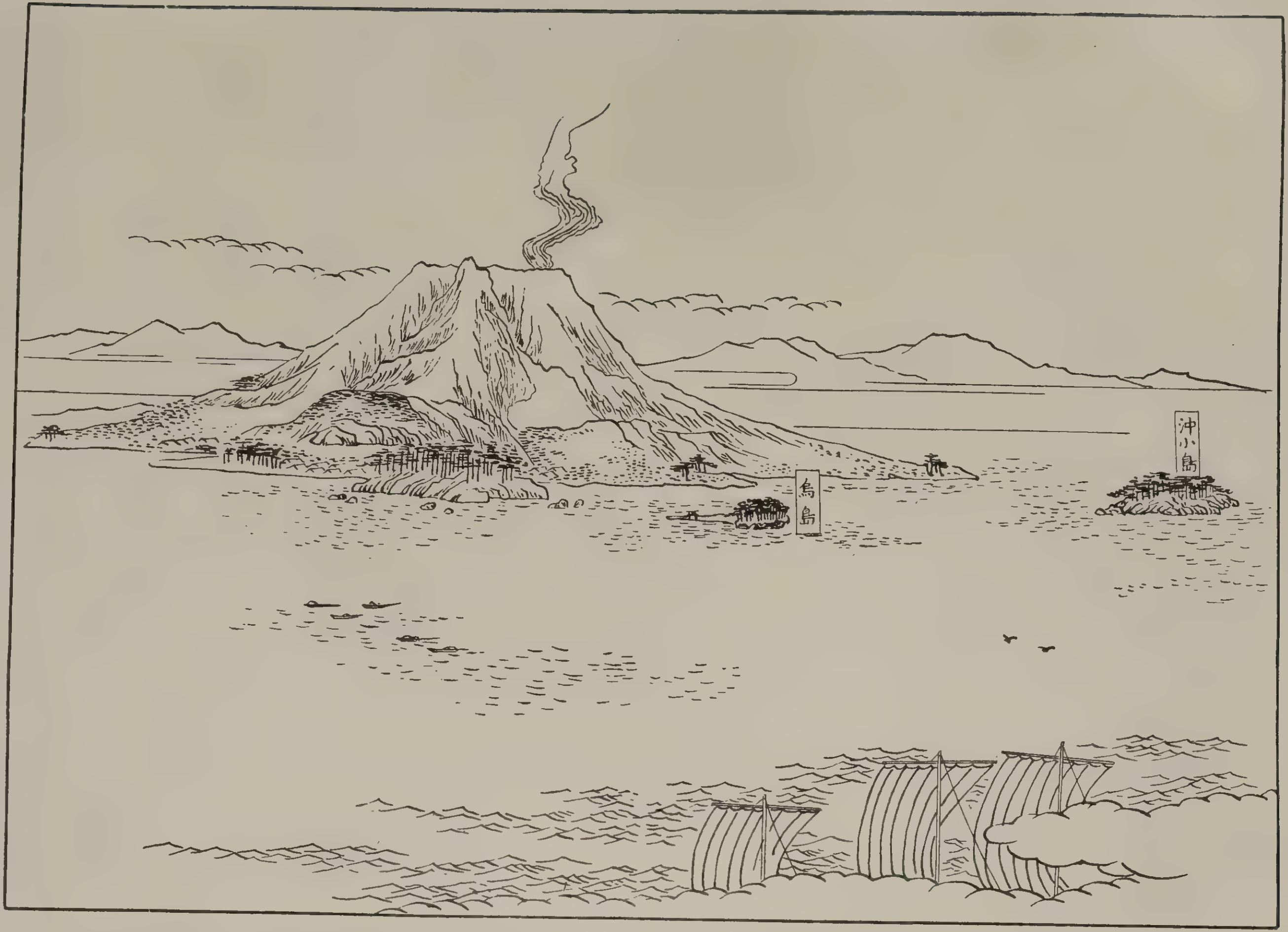


Fig. 4. Sakura-jima, as it appeared from Kagoshima 70 years ago, with the islets of Karasu-jima and Oko-jima respectively near the middle and at the right-hand side of the picture.
(Reproduced from the "Sangoku Meishō Zue.")

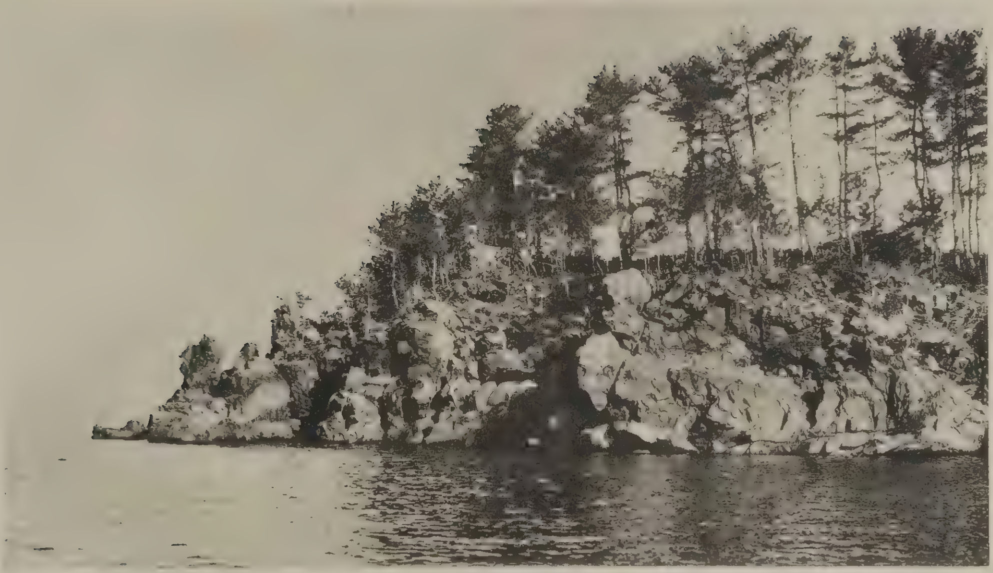


Fig. 5. Moe-Zaki, ("Burning Cape") at the S.W. end of Sakura-jima, formed by the lava flow of 1476.

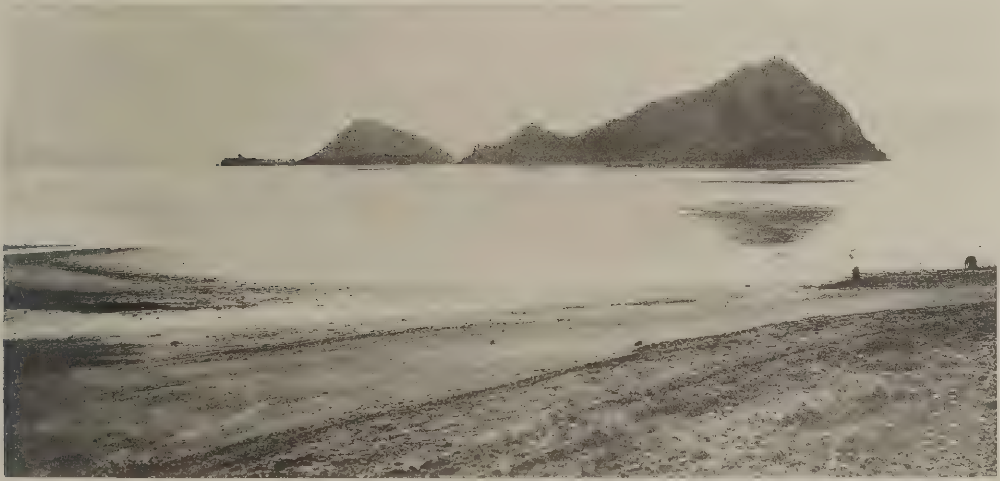


Fig. 6. View from N.E. of Kanzukuri-jima ("Islets created by gods"), the Heta-Kojima and Oko-jima of the present day, formed in 764 near the N. coast of Kagoshima Bay.

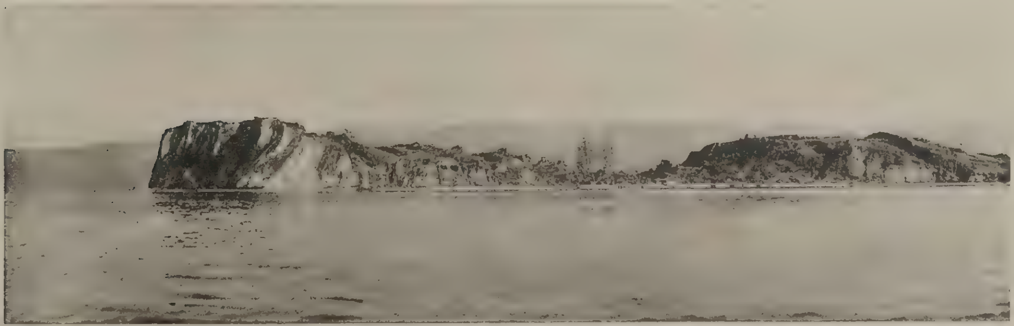


Fig. 7. View from W. of Moe-jima ("Burning Islet"), formed in 1780 off the N.E. coast of Sakura-jima.

(F. Omori, photo.)

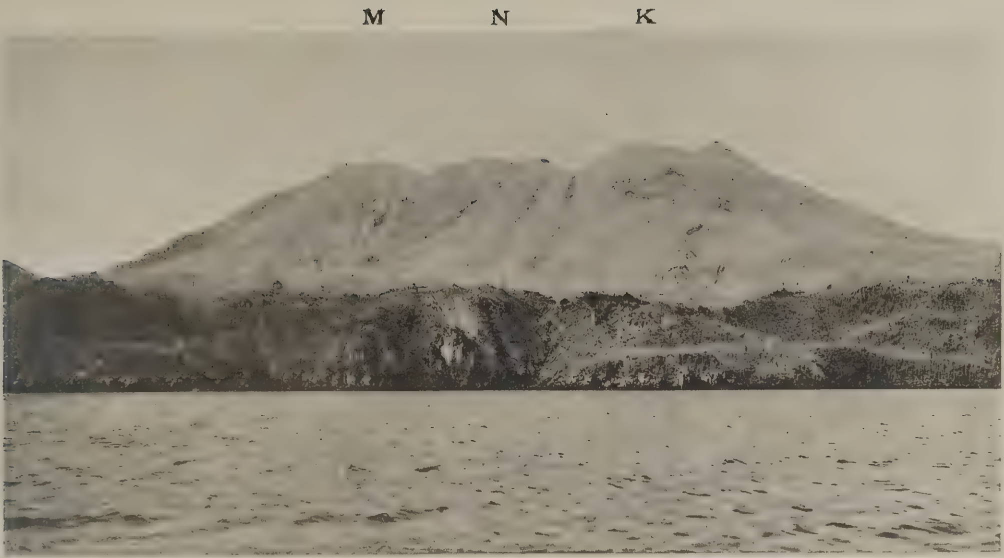


Fig. 8. View from N.E. of Sakura-jima with Kita-dake (K), Naka-dake (N), and Minami-dake (M) tops arranged from right to left. At the upper flank of Kita-dake, there are shown two old large side "Higona", or craterlets. In the fore-ground, at the middle, there stands the half buried Sono-yama, with lava flows of 1779 on both sides. (F. Omori, photo.)

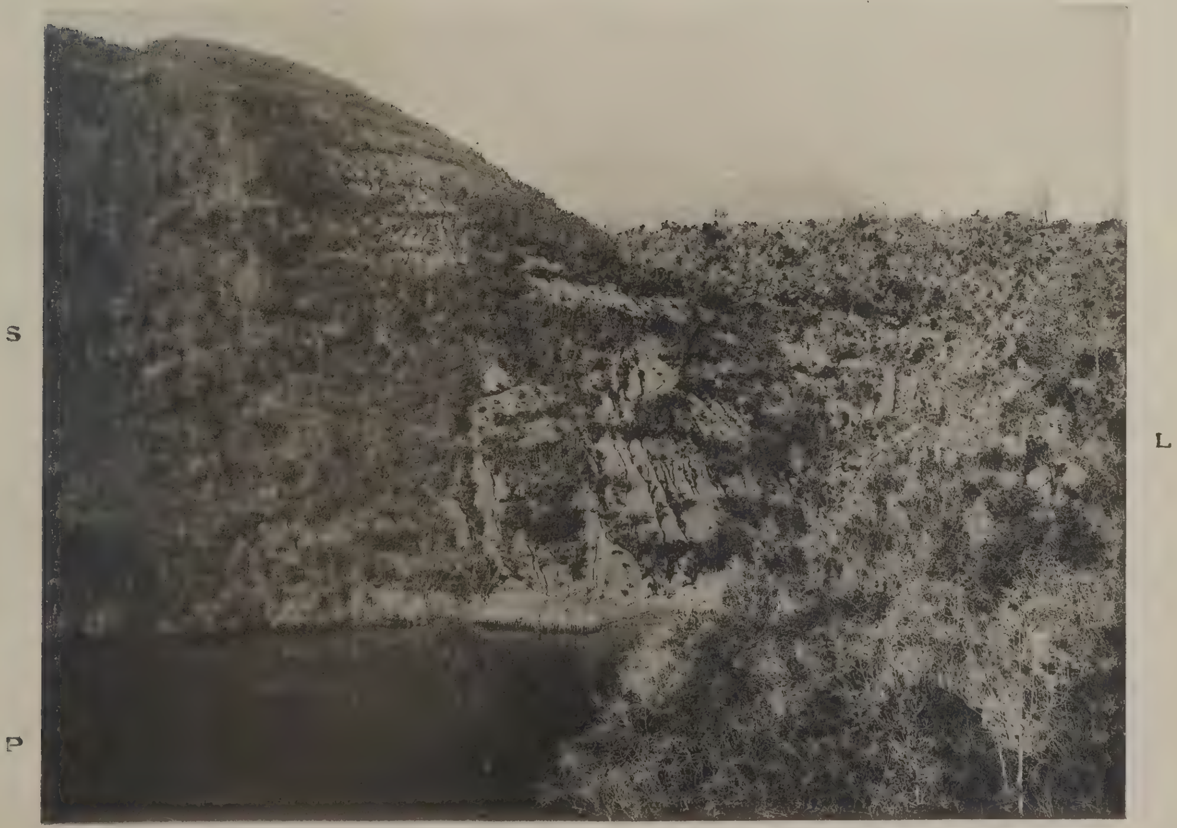


Fig. 9. Sono-yama (S) and Pond (P), with the lava flow (L) of 1779 at the right-hand side. Kita-dake and Naka-dake tops are shown on the back-ground. (F. Omori, photo.)

government, prayers were being fervently offered in the nine principal Buddhist temples of the city for the pacification of the volcanic disturbances, when, at about 4 o'clock on the same afternoon, strong outbursts took place also from the N.E. slope of the mountain, at a locality termed Kamekake (瓶掛), above the old village of Komen (高免).

The violence of the eruption was considerably augmented about 12 hours after the commencement, namely, in the early morning of the next day, Nov. 10th. Thus, at the village of Futamata (二股), on the N. coast of the island, hot lava fragments began to fall there from about 3 a.m. on the 10th; while, in the city of Kagoshima, the detonations became specially strong from about 5 a.m. on the same day. It is probable that the eruption entered in the morning of the 10th on its phase of the maximum explosive activity, followed then by the epoch of the lava outflow. Thus, the lava stream on the Furusato side probably flowed out on the night of Nov. 11th, as it is recorded that an Arimra villager, who had been staying at Akamizu to partake in the festival of that place, thence walked on the same day along the south coast of the island to the village of Seto without encountering any lava stream at all. In fact, the Anei lava at Furusato is not covered by pumice and consequently must have flown out subsequent to the heavy precipitation of the latter.

The eruption was most active on Nov. 9th and 10th. At Tarumizu and the neighbourhood, to the S.E. of Sakura-jima, the smokes became thinner on the next two days, the sky becoming gradually clear after one week, on the 16th. The weather, which had remained fair during the first three days of the eruption, changed on Nov. 12th, when, in Kagoshima, there was first, under an easterly wind, a precipitation of ashes and the air became dark between 10 a.m. and 2 p.m. Ashes fell there also on the 13th and 15th of the same month.

Detonative sounds. The sounds of the eruption must of course have been perceived at a considerable distance from the volcano. Thus, at the city of Ōita, 206 km to the N.E.N. of Sakura-jima, sounds like gun boomings were heard during the night of the 8th and on the 9th, Nov. At the much nearer town of Miyakonojō, there were 5 or 6 earthquakes during the night of Nov. 8th, and the sky became cloudy from about the noon of the next day, when sounds like thunders began to be heard.

Ash-precipitation. According to § 18, the accumulation of pumice on this occasion was very thick in the eastern and southeastern parts of Sakura-jima, being about 2.3 to 2.8 m at the Arimra-Yunohama beach terrace, and 1.03 m at Krokami. The precipitations at these two places were due to the eruptions respectively from the S. and the N.E.N. side craterlets. Outside the island, the accumulation was thickest and amounted to 3–6 ft on the Sakkabira (Hayasaki) promontory and at the village of Obama, on the coast of the province of Ōsumi, and 4.8 to 5.4 km to the E.S.E. of the Furusato side craterlets, thence gradually diminishing southwards, till it was reduced to about 0.25 ft at Tarumizu, 11 km to the S.E.S. of the same sources of eruption. On the N. coast of Kagoshima Bay, there fell at Shikine ashes only, not mixed with sand or pumice. In the province of Hyuga, the amount of precipitation was about 10 mm at Miyakonojō and Miyazaki, and 120 mm at the town of Obi, these three places being situated respectively 42 km to the N.68°E., 83 km to the N.63°E., and 66 km to the N.86°E. of Sakura-jima.

The ashes were carried, as in the case of the eruption of 1914, principally towards the east, their slight precipitation, on

Fig. 10. Old Sketch Map of Sakura-jima Eruption in Anei Period (1779), illustrating the outbursts from different places in and out of the Island.

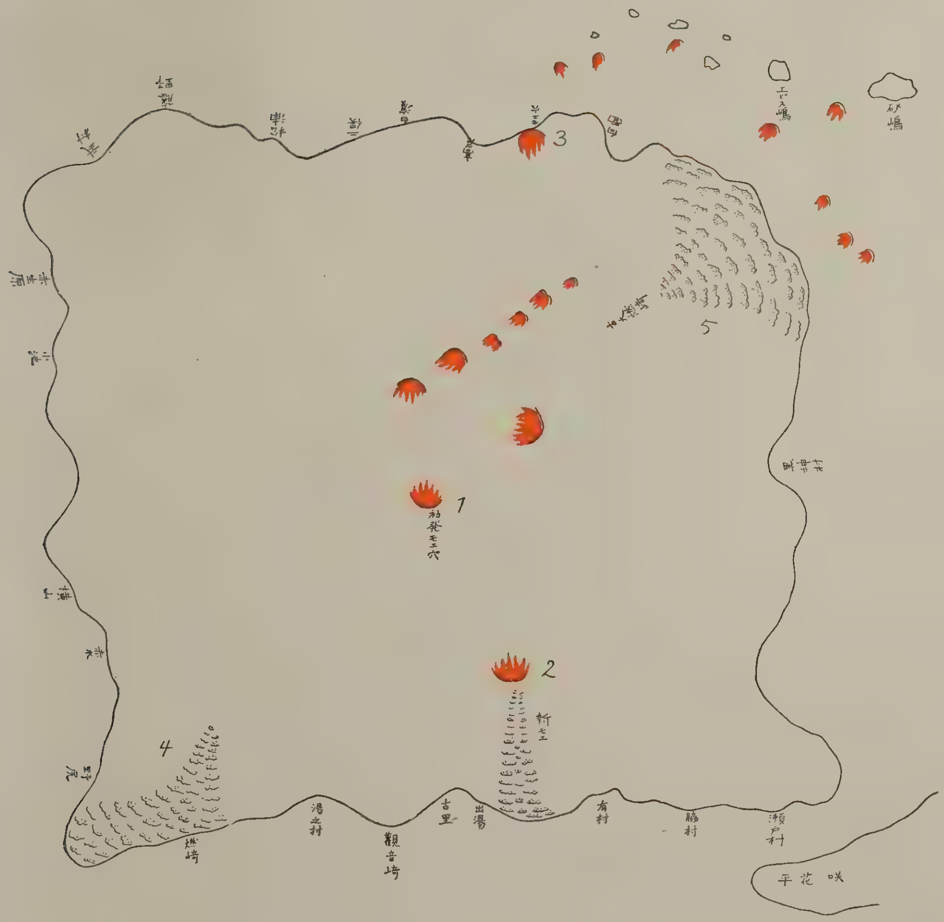
(Reproduced from Ijichi Kiken's "Accounts of the Personal Experiences in the Anei Catastrophe.")

(1) Craterlet whence the first or earliest eruption took place.

(2) Source of the Furusato Lava Stream.

(3) Craterlet still remaining in the vicinity of the present village of Komen.

(4) Moe-zaki (Bummei Period). (5) Ōmoe-zaki (Bummei Period).



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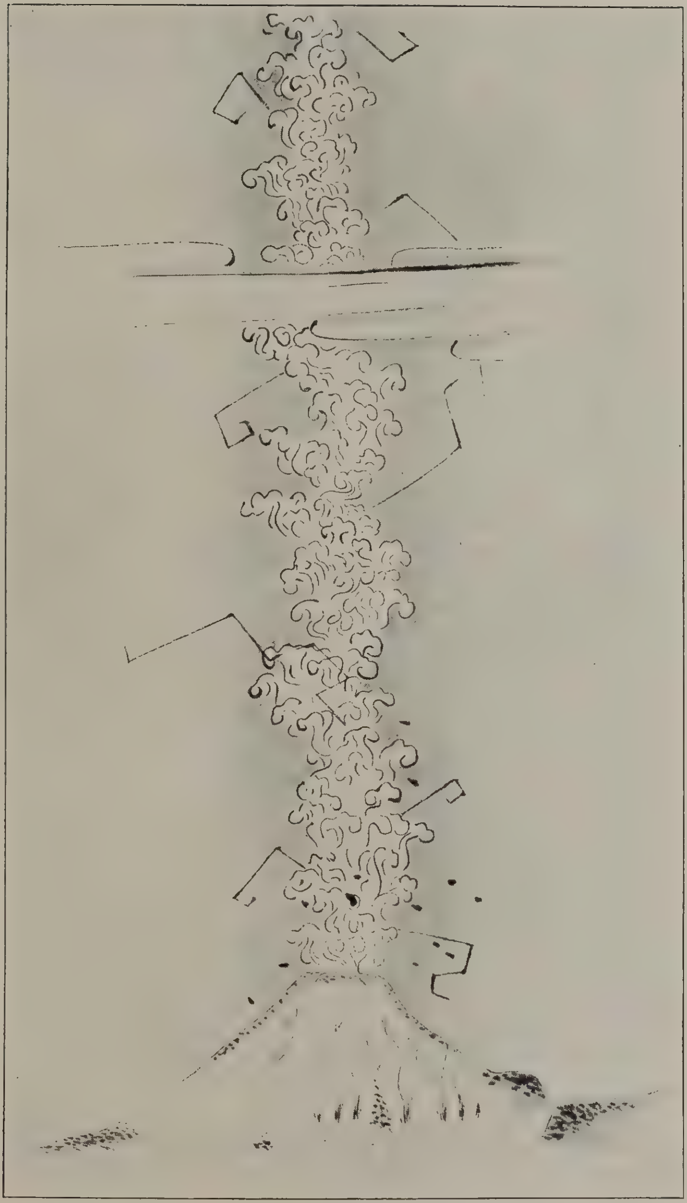

Fig. 11. View of Sakura-jima taken from Tarumizu, illustrating the first outburst in the eruption of 1779. The crooked lines shooting out of the smoke column are the symbolical representations of lightning flashes. The original drawing is given by Ijichi Kiken in his " Accounts of the personal experiences of the Anei catastrophe."

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Nov. 10th and 11th having been reported from the coast of Tosa, and some places in Kii, Owari, Ise, and the Kuanto provinces. In Yedo (Tokyo) it was cloudy and cold on Nov. 9th, and the ashes which had began to fall in the night of the 9th, like mist or snow, ceased on the 10th, when the weather became fair. In Osaka, there was some precipitation of sand on the 9th. At the town of Tanabe, on the S.W. coast of the peninsula of Kii, the precipitation of ashy sand, which continued from about 8 p.m. on the 8th till the morning of the 9th, was some 3 mm in thickness, the amount being greater along the S.E. coast of the same province. In Nagasaki the ashes began to fall from the evening of the 9th.

Assuming the ashes thrown out by the first outburst of Sakura-jima on Nov. 9, at about 11 a.m. to have been carried to the distant places named above, their progress through the radial distance of 960 km to Yedo took about 12 hours, giving the high mean velocity of 80 km or 50 miles per hour. On the other hand, the precipitation of ash and sand at some places nearer the volcano occurred after a comparatively long time interval. Thus, at Miyakonojō, the ashes (white sands) began to fall only at 4 p.m. on the 9th, or about 5 hours after the commencement of the eruption.

10. Sono-yama and pond at Moto-Komen. Sono-yama, which is a small solitary hill, 78 m in height, situated near the N.E. coast of Sakura-jima and opposite Moe-jima, was not buried by the lava flow in the Anei period, 1779. As will be seen from figs. 8 and 9, (Pl. XIII), the lava which enveloped the hill from back was divided into two branches and descended along the two sides, and again uniting at the front, have formed a small pond 70 m long and 50 m wide. The shortest distance between the pond and the sea is

100 m and is along the line of confact of the two lava branches, whose height is 6 to 8 m above sea surface. The water in the pond, which is blue and salty and has a depth of about 7 fathoms, rises and falls with the tide motion of the external sea, there being apparently some sort of communication between the two bodies of water. In fact, the old lavas forming the projecting coasts of the island, namely, Nishiseko-hana, Kwannon-zaki, Ōmoe-zaki, Moe-zaki, etc., are very discontinuous, being broken through with wide and deep chasms and also with cavities of different size. Hence it must be quite easy for the sea water to permeate for not a small distance inward from the actual coast.

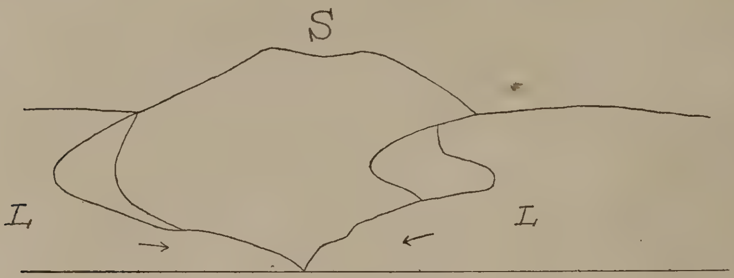

Fig. 12. Sono-yama seen from sea (E.N.E.).
S....Sono-yama. L....Lava flow of 1779.

The neighbourhood of Sono-yama is called Moto-Komen, (" Old Komen "), because it is the original site of the village of Komen. To the east of the hill there had existed, before the Anei period, a small inlet, wherein two large fishing vessels could lay at anchor. As the old village was buried under the lava in 1779, the inhabitants emigrated to the vicinity of the town of Kokubu at the north coast of Kagoshima Bay, but came back after the lapse of 27 years and settled at the present site of Komen.

The small narrow sea-coast place of Uranomae, ½ km to the S.E. of Moto-Komen belonged originally to the old village of Komen. It is bounded on the W. side by the terminal and side "embankments" of the Anei lava flows, and on the E. side by Ōmoe-zaki, or lava stream of the Bummei (1471) eruption.

A large "dry lake," or depression area, about ½ km in length, near the junction of the Krokami and Uranomae roads, is an uncovered or lava-free piece of ground, which probably had formed the outside slope of a hill. Similar, but smaller, spots exist also in the vicinity of Sono-yama.

11. Damage caused by Anei outburst, and after-eruptions. According to the official report under the date of Jan. 15th, 1780, the damage caused by the eruption consisted of the death of 79 men and 74 women, beside 285 horses killed, and of the destruction of 13 temples, 500 houses, and 12 boats, the injuries to the cultivated fields amounting to 10,520 *koku* in permanent loss and 13,041 *koku** in temporary loss.

The inscription on a stone monument (櫻島燃亡靈等碑), erected in the winter of 1779 on the ground of the Nanzenji temple in Kagoshima to the memory of the unfortunate victims, put the number of the latter at the different Sakura-jima villages at 148, as follows:—Furusato, 6; Arimra, 57; Waki, 34; Seto, 46; Krokami, 5. Thus the amount of casualty was greatest at the three villages of Seto, Waki, and Arimra, at the S.E. coast of the island, while there was no loss of life at Komen, on the N. coast, which occupied the site now known as Moto-Komen and was entirely buried under the lavas. Again, the houses in Furusato, Arimra, Waki, and Krokami, were almost entirely burnt down by volcanic ejecta. At Seto, however, there remained some houses standing, as the shortest radial distance was 4 km and the fiery lava pieces were precipitated there only to a slight amount, on account of a sufficient removal of the village from the craterlets. The disastrous consequences of the great volcanic convulsion lasted for a long succeeding time interval, and according to the 2nd official report under the date of July 27th, 1780, there was a further addition of the temporary damage to cultivated field to the amount of 15,651 *koku*, beside 21,500 mandarin orange trees and 129,500 other trees destroyed, while 1,576 horses and 135 cattle died from the want of forage.

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* 1 *koku*, a Japanese measure used for both wet and dry goods, is equal to 5.0 bushels or 180.4 litres.

On Sept. 9th, 1780, at midnight, a submarine outburst took place, which sent up fires and smokes to a considerable hight, causing "tsunami," whose waves were 20 ft high at the beach of Koike on the W. coast of Sakura-jima, at the N.E. base of Hakamagoshi. The official report under the date of Nov. 28th, 1780, states that some of the new islets, which had arisen off the N.E. coast of Sakura-jima, gradually increased in size, and that the stronger submarine eruptions were accompanied by large sea-water disturbances, which rushed in over the neighbouring coasts and also flooded the strand streets of the Kagoshima city. The damage resulting from these "tsunami," up to Sept. 1780, was as follows :—permanent and temporary losses to cultivated field, respectively 675 and 17,647 *koku* ; numbers of houses completely and partially destroyed by the waves, respectively 168 and 630 ; habitation grounds washed by sea-water, 417 pieces ; lengths of broken embankment roads, masonry walls, and river banks, respectively 11,380 ; 1,237 ; and 670 *ken*.*

On April 11th, 1781, at about 4 p.m., outbursts took place from several points under the sea near the new islet (Moe-jima) as well as from the older land craterlets and threw up mud, ash, and sand, accompanied by earthquakes, causing a "tsunami," upsetting three boats at Uranomae (between Moto-Komen and Ōmoe-zaki, and opposite the Moe-jima islet) and drowning 14 men and 1 woman who had come from Matsuura (松 浦), Shirahama (白 濱), and Taniyama (谷 山), for fishing or collecting fuel thereabouts. On this occasion, there was at Koike the in-rush of large waves 10 times repeated, while mud rain fell at Krokami and Seto to the thickness of nearly 1 foot. On May 1st, 1781, detonations and outbursts followed from the same sites as on the preceding occasion. The damage due to these disturbances was as follows:—temporary loss to cultivated field, 1503 *koku*; number of houses partially and completely destroyed by the waves, respectively 672 and 23; habitation grounds washed by sea-water, 273; broken bridges, 6; lengths of broken embankment roads, masonry walls, and river banks, respectively 7,349; 1,190; and 1,625 *ken*.

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* 1 *ken*=6 feet very nearly.

On Jan. 18th, 1782, at 4 p.m., submarine eruptions took place off the coast of Moto-Komen, the firely smokes being well observed from Koike. None of the subsequent eruptions was submarine.

On Nov. 20th, 1785, at midnight, outbursts with low detonative sounds took place from the former craterlets, which, though of a short duration, were attended by flashes of lightnings and sent up fires and smokes to a great height, precipitating ash at Seto and some pumice at Krokami. The people fled across to Ushine and Tarumizu, but there was no casualty.

12. Anei new islets. Fig. 10 is a reproduction of the map given by Ijichi Kiken, of Tarumizu, in his accounts of the personal experiences in the Anei catastrophe, indicating the eruptions from a number of points, several of which were situated off the N.E. coast of Sakura-jima. The remarkable consequence of the numerous submarine outbursts was the production in the 8th and

9th years of Anei of a number of islets, within the maximum distance of 3.1 km from the coast, between Nishiseko-hana and Uranomae, whose order of appearance was as follows :—

			Japanese Calendar [8th Year of Anei.]		European Calendar.
1st Series	No. 1.	Ichiban-jima.	10th month,	14th day	Nov. 21st, 1779.
	No. 2.	Inoko-jima.	,, ,,	15th ,,	,, 22nd, ,,
	No. 3.	Nakano-shima.	11th ,,	6th (night)	Dec. 13th, ,,
	No. 4.	Iwo-jima.	12th ,,	9th (,,)	Jan. 15th, 1780.
			[9th Year of Anei.]		
2nd Series	No. 5.	Moe-jima.	4th month,	8th day	May 11th, 1780.
	No. 5′		,, ,,	,, ,,	,, ,, ,,
	No. 6.	Doro-jima.	6th ,,	11th ,,	July 12th, ,,
	No. 6′		9th ,,	2nd ,,	Sept. 29th, ,,
	No. 6″		10th ,,	13th ,,	Nov. 9th, ,,

Of the new islets, whose original number was nine, the four of the 1st series were composed of lava, and remained separate. On the other hand, the five of the 2nd series were composed of pumice and sand, and suffered subsequent unifications in two groups, due probably to the elevation of their bases.

No. 1 lava island again disappeared under water 8 months 10 days after its formation, namely, on Aug. 1st, 1780. The two sandy islets, Nos. 5 and 5′ were amalgamated into one 23 days later on, namely, on June 3rd, 1780, the result being the Moe-jima of the present day. The three other sandy islets, Nos. 6, 6′, and 6″, were also subsequently connected into one, called Doro-jima (Mud Island) or Yebisu-jima (Fisherman's Island), the latter name having been given on account of the abundance of fish in its neighbourhood.

The 4 lava islets of the 1st series were formed successively from W. toward E. between Nov. 21st, 1779, nearly 2 weeks from the day of the first Anei outburst, and Jan. 15th, 1780, or during the 54 days immediately after the decline of the eruptive activity. The two groups of the sandy islets were, on the other hand, formed between the 6th and 12th months after the commencement of the eruption. This wide difference in the dates of formation of these two series of islets seems to point out also a dissimilarity in their nature.

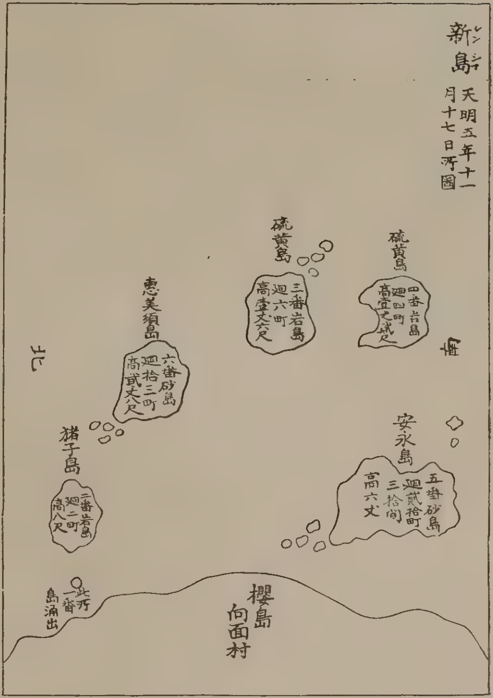

Fig. 13. Map of the Anei new islets formed off the coast of Moto-Komen, drawn on Dec. 18th, 1785, giving the height and circumference of the five principal ones. From left (north) to right (south), Inoko-jima, Doro-jima (Yebisu-jima), Iwo-jima (Nakano-shima), Iwo-jima, and Moe-jima (largest).

According to fig. 13, which is a reproduction of a drawing made on Dec. 18th, 1785, as well as according to an official document under the same date, the three lava islets of Inoko-jima, Nakano-shima, and Iwo-jima were low in elevation and had the heights respectively of 8, 16, and 12 *shaku* while the two sandy islets of Moe-jima and Doro-jima were respectively 60 and 28 *shaku* in height. The comparison of the former, with the present, dimensions of the islets in question is given in fig. 14 and is as follows:—

Islets.		Dimensions*		
		in 1785.		at the present time.
		Height.	Circumference.	
Lava Islets.	Inoko-jima.	8 *shaku.*	2 *cho.*	At high tide, entirely covered by water, except two or three points.
	Nakano-shima.	16	6	Height = 22 *shaku.* Cirfce = 4 *cho.*
	Iwo-jima.	12	4	„ 9 „ „ 5 „
Sandy Islets.	Moe-jima.	60	20½	„ 145 „ „ 16 „
	Doro-jima.	28	13	Almost entirely covered by water, except two or three points.

* 1 *shaku* = 1 foot very nearly ; 1 *cho* = 360 *shaku.*

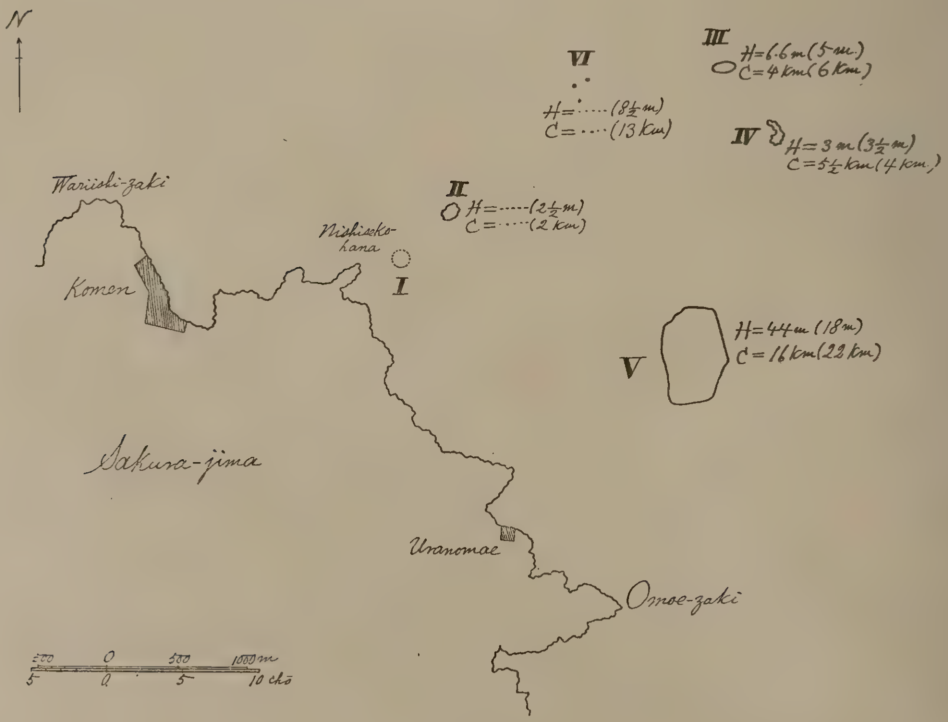

Fig. 14. Map of the Anei Islets, indicating the height (H) and circumference (C) in 1785. The corresponding numbers, measured from the 1/50000 Military Survey map (previous to the recent eruption), are given in brackets.

I....Ichiban-jima (submerged). II....Inoko-jima. III....Nakano-shima.
IV....Iwo-jima. V....Moe-jima. VI....Doro-jima.

The circumferences of the different islets seem on the whole to have been lessened since the Anei period, the diminution being specially marked in the case of Doro-jima.

The new Anei islets rose, according to the documents of the times, from the sea bottom originally 70 to 90 fathoms in depth. This looks likely enough from an inspection of fig. 3, the portion of Kagoshima Bay to the north of Sakura-jima having nearly an uniform depth of 70 to 80 fathoms, except about the islets in question off the N.E. coast of the island, where the water is shallow. (See fig. 16.) The submarine extension of the lava of 1779, which is most marked about Cape Nishiseko-hana, seems to end at a distance of only about 1 km from the apex of the latter, and the line of 50 fathoms depth which includes the Anei islets and extends about 4 km from the N.E. coast of Sakura-jima, marks approximately the boundary of the area probably elevated during the eruption in question, being separated from the latter coast by a narrow ditch of depth greater than 50–70 fathoms, to be supposed to represent the remnant of the original sea bottom. The three islets of Inoko-jima, Nakano-shima, and Iwo-jima, together with the submerged Ichiban-jima, lie roughly on a straight line joining the land craterlets of 1779, and seem to have been the results of lava eruptions from the sea bottom subjected to a previous elevation. The formation of two sandy islets of Doro-jima and Moe-jima, which have an extensive submerged base and together constitute a shoal parallel to the coast and normal to the craterlets zone above mentioned, may not be the direct result of submarine eruptions, but be due entirely to the elevation phenomena.

Fig. 15. Moe-jima (Anei-jima) seen from W.

This supposition was also put forward by Mr. K. Yamaguchi, of Kagoshima Girls' Normal School, who found shell fossils among the pumice layers of Moe-jima. The latter has a series of transverse stepwise dislocations, which dip down southwards, apparently indicating the location of the centre of elevation between the two sandy islets. Fig. 7, Pl. XII, is a west side view of Moe-jima, taken in Sept. 1914 from a near distance. The village occupies the low ground at the middle between the N. and the S. elevations. The islet was inhabited first in May 1800, or nearly 20 year after its formation in the 9th year of the Anei period.

It is interesting to note that the centre of depression caused by the great recent eruption of Sakura-jima is situated under the sea to the north of the island, adjacent to the above-mentioned area elevated subsequent to the Anei (1779) eruption.

13. Condition after the Anei eruption. After the great eruption of Anei (1779), the volcano caused ash-precipitation at intervals even as late as 1809 ; the sounds like distant thunders being sometimes heard with easterly winds in the city of Kagoshima. It is thus probable that the slight eruptive disturbances did not completely cease for more than 30 years. In the earlier part of the Meiji era, which began with 1868, only white smokes were issuing from the top of Minami-dake, and it is said that these vapours became much abundant between the end of 1878 and about March of the next year. More recently, the white smokes from the top decreased very much, such that these could be observed from the city of Kagoshima only once or twice each year ; the mountain having continued in this state till the occurrence of the great outburst of 1914. Almost simultaneously the Ōshima (Izu) was undergoing a similar change in the volcanic activity ; its smokes, gradually reduced in amount, finally stopped completely in 1909–10, as a

Pl. XVI.

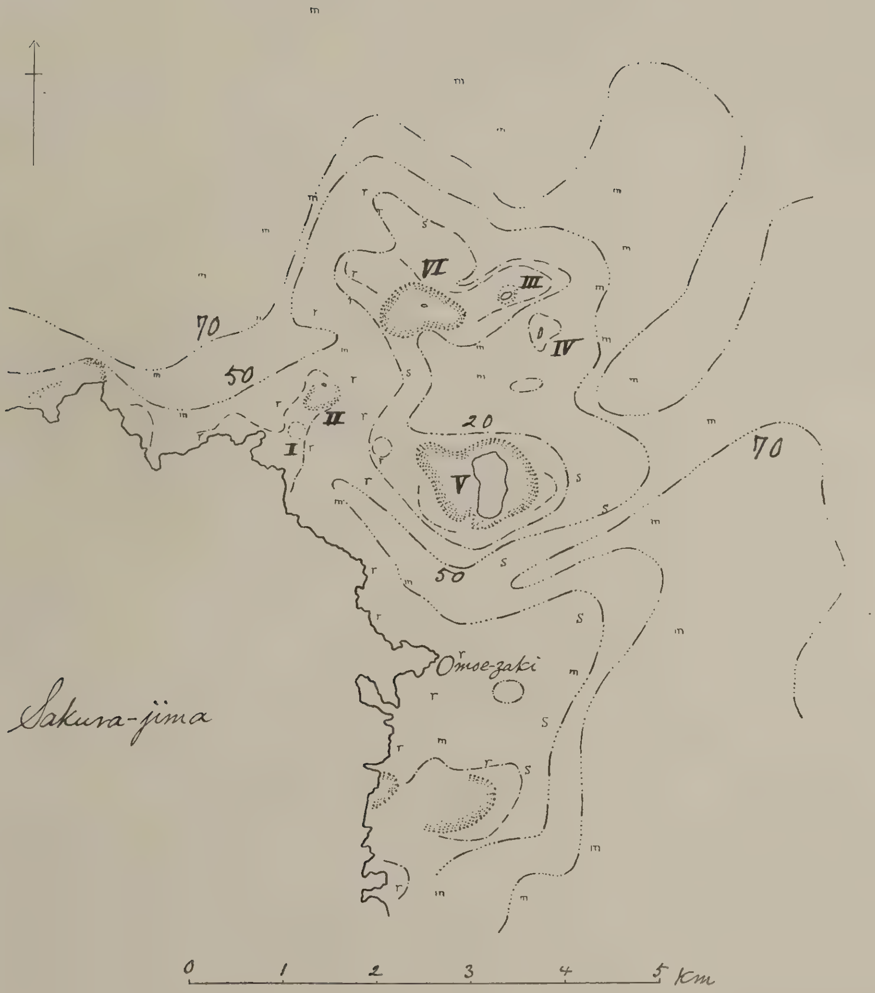

Fig. 16. Map showing the Sea-depth about the Anei Islets.
(The depth is given in fathoms.)
I . . . . No. 1 Islet (submerged). II . . . . Inoko-jima. III . . . . Nakano-shima.
IV . . . . Iwo-jima. V . . . . Moe-jima. VI . . . . Doro-jima.

precursory event to the great eruption of the mountain in 1912. A temporary extinction of once abundant smoke emission from a volcano seems thus to be often the first stage in the course of a subsequent strong outburst.

Fig. 4 is a fac-simile of a picture given in the "Sangoku-Meishō Zue," a collection of historical and geographical informations relating to the three Shimazu provinces of Satsuma, Ōsumi, and Hyuga, compiled in 1844, and represents the view of Sakura-jima taken from Kagoshima city, with the islets of Oko-jima and Karasu-jima at the right-hand side, the latter of which has been buried by the lava flows of 1914.

14. SUMMARY. The 26 eruptions of Sakura-jima between 1476 and 1914 may be grouped more or less distinctly into 3 principal activity epochs, I, II, and III, and two auxiliary epochs, II,A and II,B, both premonitory to II, (Table IX), namely, as follows.

I: *Active eruption epoch.* This extends over 8 years, 1468 to 1476, and includes the 5 eruptions Nos. 1 to 5, amongst which those in 1471, 1475, and 1476 were large outbursts.

II,A: *Epoch of premonitory disturbances.* There were 4 small eruptions, Nos. 6 to 9, which occurred in the course of the 100 years, 1642 to 1742, at the successive intervals of 36, 28, and 36 years, with the mean of 33 years.

II,B: *Epoch of premonitory disturbances.* This extends over 24 years, 1742 to 1766, from the eruption No. 9 to the eruption No. 13, all of which were also small, and whose successive intervals were much shorter than in the preceding epoch, being respectively seven, seven, and ten years.* 13 years after the eruption No. 13, there took place the catastrophe of the 8th year of

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* Taking simply the years of occurrence of eruptions, or counting as one the two disturbances in June and July, 1766.

Anei (1779). The mean interval during this epoch was about 9 years.

II: *Active eruption epoch.* The great eruption of 1779 (No. 14), which began on Nov. 9th and diminished in intensity after a few days, continued to be followed for about 12 months by frequent volcanic outbursts. Further, during about 20 years between Sept. 9th of the next year and March 27th, 1799, there were 10 small eruptions: of which the five, Nos. 15 to 19, happened in the course of the earlier 16 months, and were each a submarine outburst accompanied by a "tsunami," or sea-water disturbance. The subsequent eruptions were different in character, each being a small explosion in the island, probably from a former craterlet, which caused some ash-precipitation, but was accompanied by no "tsunami." During the 115 years between the II. and III. epochs, there was no eruption, with the single exception of No. 25, which probably consisted in a slight ash-ejection.

III: *Great recent eruption.* Jan. 12th, 1914 to April 1915.*

In each of the three great eruption epochs I, II, and III, there took place a marked lava outflow from a number of craterlets arranged at two nearly opposite sides or bases of the mountain: in I, at the E.N.E. and S.W. sides; in II, at the N.E.N. and S. sides; and in III, at the E.S.E. and W.N.W. sides. The course of eruption in the I. epoch differed, however, in a marked way from those of the II. and III. epochs. Namely, in each of the two latter, the lava outflows took place from the two opposite mountain sides simultaneously, i.e., with the time difference of only a few minutes or a couple of hours; while in the case of the I.

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* As pointed out in No. 1, of this Volume, the Strait of Seto, between Sakura-jima and the mainland of Ōsumi has actually been blocked up on Jan. 29th, 1914, converting the island actually into a peninsula. In these pages, however, Sakura-jima is still often termed an island, meaning thereby the former insular volcano.

epoch, the first outburst occurred in 1471 at the E.N.E. part of the island, followed by two strong ones at the S.W. part respectively about 4 and 5 years later on. It seems probable that the underground tension, or the intensity of the volcanic force, reached a greater accumulation in the two later epochs, necessitating a simultaneous opening of several craterlets along a fissure or line of weakness, and from both flanks of the mountain.

15. Lava areas and craterlets of the different eruptions. Fig. 2, which is to replace the preliminary map (Pl. 2) given in the preceding Number of the Bulletin, embodies the results of my researches respecting the areas of the lava outflows and the positions of the craterlets of the I. (Bummei, 1468–1476), II. (Anei, 1779), and III. (Taisho, 1914) great eruptions. The extension of the lava areas is, leaving out the portions under sea-water, as follows :—

				Total Area.
I. Epoch (Bummei)	E.N.E. Branch		4.3 sq. km.	6.4 sq. km.
	S.W. „	(Higher or 1st Stage Area)	0.8 „	
	S.W. „	(Lower or 2nd Stage Area)	1.3 „	
II. Epoch (Anei)	N.E.N. Branch		4.8 „	6.1 „
	S. „		1.3 „	
III. Epoch (Taisho)	E.S.E. Branch		8.5 „	16.8 „
	W.N.W. „		8.3 „	

Thus the land lava area of the III. (1914) eruption was very extensive and is nearly 17 sq. km, or 1.3 times those of the I. (Bummei) and II. (Anei) eruptions put together.

16. Volcanic eruption and lunar age. That volcanic eruptions are more frequent at the time of high tide is a generally accepted idea, which is recorded also in the old accounts of the Anei period catastrophe, and which is verified more or less in the cases of the *strong* Sakura-jima outbursts. Thus the latter, five in number, happened as follows :—

No. 14,..	.. ..	1st lunar day.
Nos. 4 and 26,	.. ..	15th ,,
Nos. 2 and 5,	.. ..	2nd ,,

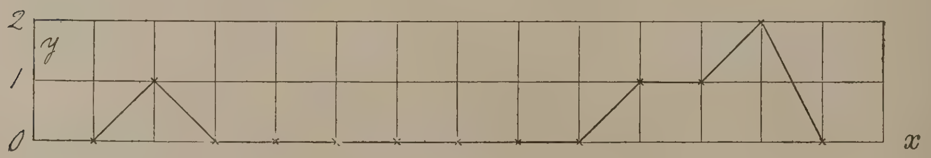
The occurrence of these Sakura-jima strong eruptions at the time of the new moon and at or near the full moon is certainly a noteworthy fact. The great outburst of the Taal Volcano (Manila), in 1911, commenced its final or most active phase on the 30th of January, which also corresponded to the 15th lunar day.

17. Annual distribution of eruptions. The annual distribution of the 23 Sakura-jima eruptions, of which the month of occurrence is known, is as follows:—

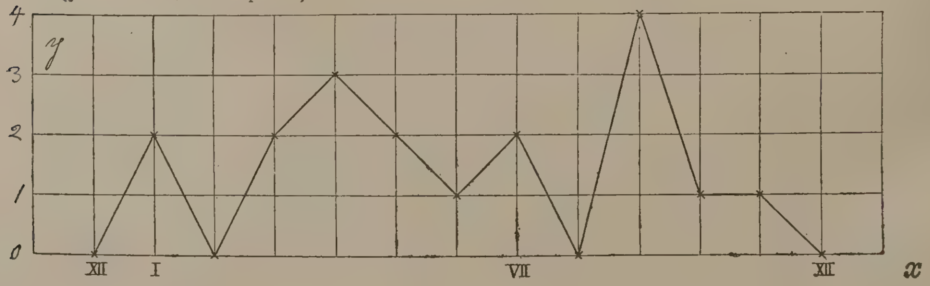
Month.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Number of Strong Eruptions.	1	0	0	0	0	0	0	0	1	1	2	0
Number of Small Eruptions.	2	0	2	3	2	1	2	0	4	1	1	0

Fig. 17. Annual Distribution of Sakura-jima Eruptions. (x=month.)

(y=Number of large eruptions.)



(y=Number of small eruptions.)



Thus the strong Sakura-jima eruptions occurred exclusively in September to January, while the small ones indicated a tendency of an opposite annual frequency variation and occurred mostly in March to September. (See fig. 17.)

18. Accumulation of pumice and formation of soil. The extensive lava flows and the thick accumulation of pumice and ash caused by the recent eruption of Sakura-jima naturally formed or modified the courses of several ravines and streamlets in the island, producing in some places nicely cut sectional exposures which indicated the local amount of pumice accumulation during, and of the more or less perfect black soil formed since, the volcanic outbreaks of the last 5 centuries or more. Three well-defined examples are illustrated in figs. 18, 19, and 20.

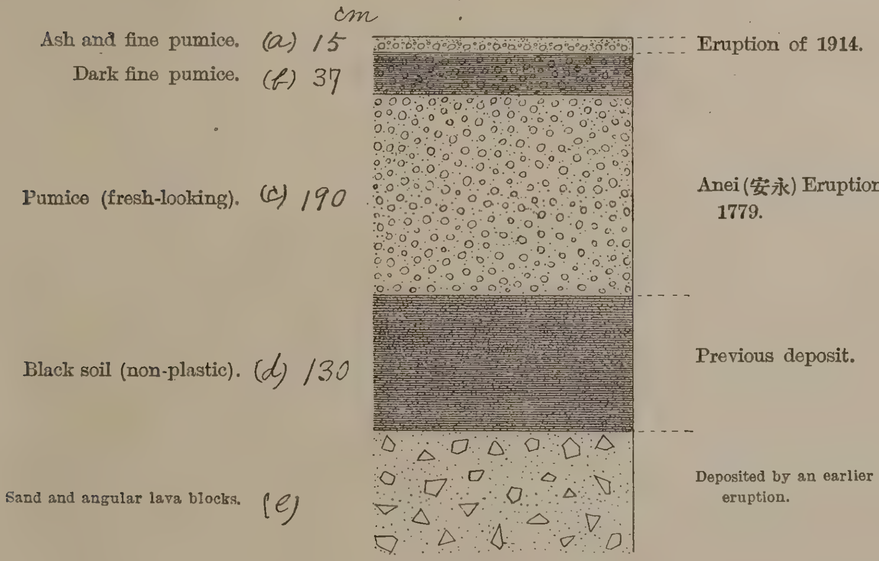

cm
Ash and fine pumice. (a) 15
Dark fine pumice. (b) 37
Pumice (fresh-looking). (c) 190
Black soil (non-plastic). (d) 130
Sand and angular lava blocks. (e)
Eruption of 1914.
Anei (安永) Eruption, 1779.
Previous deposit.
Deposited by an earlier eruption.

Fig. 18. Section showing the Accumulation of Pumice and Ash at Yunohama Beach.

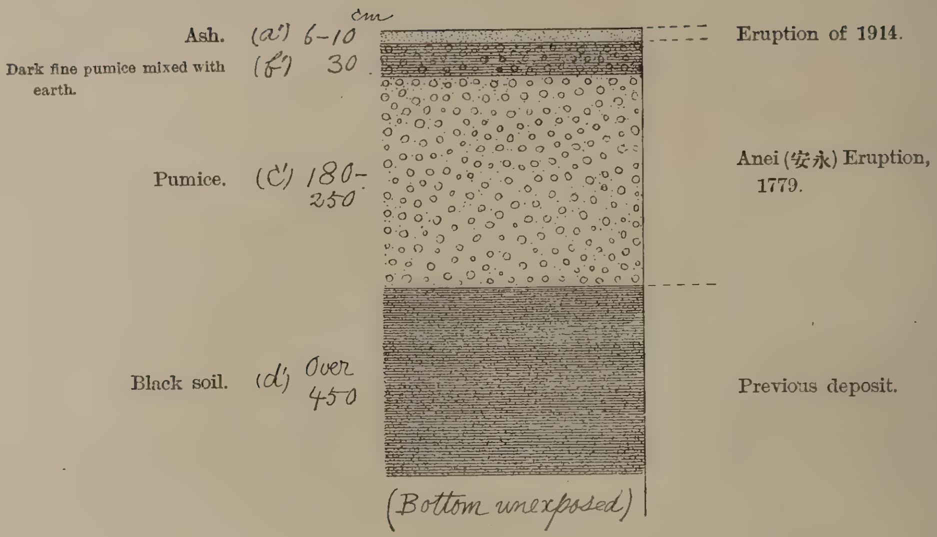

cm
Ash. (a') 6–10
Dark fine pumice mixed with earth. (b') 30
Pumice. (c') 180–250
Black soil. (d') Over 450
(Bottom unexposed)
Eruption of 1914.
Anei (安永) Eruption, 1779.
Previous deposit.

Fig. 19. Section showing the Accumulation of Pumice and Ash at Yunohama District 150–300 m above sea-level.

According to fig. 18, at the Yunohama beach close to the W. boundary of the recent S.E. side lava flow, the thickness of the new precipitation of pumice and ash was 15 cm, while the accumulation during the Anei eruption, in 1779, due to the emission from the two craterlets at the southern flank of Minami-dake, above the village of Furusato, was about 2.3 metres. Of this latter amount, the upper portion, 37 cm in thickness, is composed of fine dark pumice mixed with earth, being the partial conversion to soil of the volcanic débris accomplished during the past 135 years. Then there follows a layer of black incoherent earth, 1.3 m in thickness, which probably represents an accumulation of volcanic sand and ash converted into soil during a very long period of rest, and which is different in composition from the underlying bed made up of sand mixed with angular rock pieces.

At the height of 150 to 300 m above sea-level and to the north of Yunohama, namely, on the S.E. flank of Minami-dake 1½ to 2 km from its top, the sectional formation is slightly different. As shown in fig. 19, there the recent ash accumulation was 6–10 cm in thickness, or a little less than at the Yunohama beach. The Anei accumulation of pumice amounted from 2.1 to 2.8 m, of which the upper portion, 30 cm in thickness, had been converted partially into earth. The underlying layer of black earth, whose lower portion is not exposed, is very thick, the exposed portion alone amounting to 4½–6 m.

Finally, at Krokami, about 1 km from the E. coast, the precipitation during the recent outbursts consisted of 20 cm of surface covering of ash and 2.0 m of pumice, while that due to the Anei (1779) eruption was 1.03 m of pumice, of which the upper 13 cm has been partially converted into earth. (See fig. 20.) The

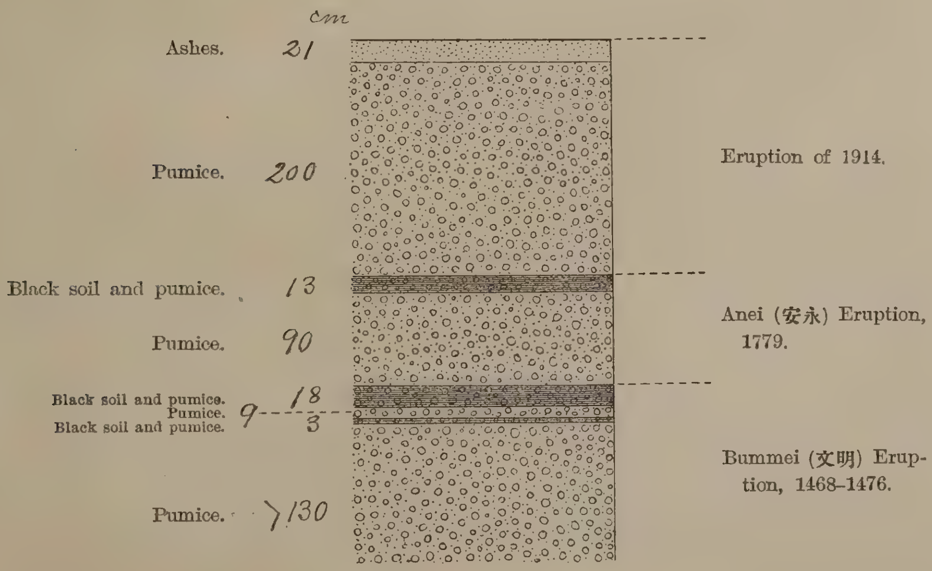

cm
Ashes. 21
Pumice. 200
Black soil and pumice. 13
Pumice. 90
Black soil and pumice. 18
Pumice. 9
Black soil and pumice. 3
Pumice. >130
Eruption of 1914.
Anei (安永) Eruption, 1779.
Bummei (文明) Eruption, 1468–1476.

Fig. 20. Section showing the Accumulation of Pumice and Ash along the Stream Bank above Krokami.

accumulation of débris during the prolonged eruptions of the Bummei period (1468–1476) is made up of pumice layer (bottom not exposed) more than 1.3 m in thickness, superposed with two thin layers of black earth mixed with pumice respectively 18 cm (upper) and 3 cm (lower) in thickness, interposed with a white pumice layer of 9 cm. In the valley grounds at the N.W. foot of Nabeyama, the new pumice accumulation in 1914 amounted to 4.0 m. The pumice layer due to the Anei (1779) eruption at the N. flank of the same hill was 1.1 m in thickness.

Comparing together the three cases mentioned above, we see that the thick layer of black earth beneath the pumice accumulation of the Anei (1779) eruption, which is absent at Krokami, is 1.3 m thick at the Yunohama beach, being increased to over 4½ m at places 150–300 m higher up. This particular layer might have been due to a thick precipitation of dusts thrown out many years ago from the Minami-dake crater,

The amount of the pumice accumulation due to the catastrophe of 1779, under the prevailing N.W. winds, was at the Krokami district only one-half of that in the neighbourhood of Yunohama; this difference having been caused by the S.E. proximity of the latter place to the Furusato craterlets, while the former was probably out of the most direct course of ash-transportation from the different craterlets of the N.E. or Komen district. On the other hand, the precipitation due to the Bummei eruption in the vicinity of Nojiri, in which the lava flow resulted in the formation of Moe-zaki, is not to be well recognized at Yunohama, while the effect of the eastern craterlets about Ōmoe-zaki is indicated at Krokami in two distinct stages, namely, a powerful outburst in 1471 with a thick precipitation of pumice, followed some years after by a much weaker disturbance.

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TABLE IX. LIST OF THE ERUPTIONS OF SAKURA-JIMA.

*. . . .Strong eruption.

Japanese Date. (Nos. 1–25, Lunar Calendar)	Group.		No.	日　本　暦	European Date.	Remarks.
Ōnin, 2nd Year.	I. Active Eruption Epoch. (**Bummei Period**.)		1	應仁二年	1468.	Burning from the mountain top.
Bummei, 3rd year, Sept. 12.			2*	文明三年九月十二日	Nov. 3, 1471.	Eruption from the Krokami side. The Ōmoe-zaki was formed.
„ , 5th „ , April.			3	同　五年四月	May, 1473.	
„ , 7th „ , Aug. 15.			4*	同　七年八月十五日	Sept. 24, 1175.	Eruption from the Nojiri side. The Moe-zaki was formed.
„ , 8th „ , Sept. 12.			5*	同　八年九月十二日	Oct. 8, 1476.	At the S.W. part of the Island, a piece of land was newly formed and was finally connected with Sakura-jima.
Kwanei, 19th year, March 7.	II, A. Premonitory Epoch.		6	寛永十九年三月七日	April 6, 1642.	Sacred burning on the mountain.
Enpō, 6th „ , Jan. 9.			7	延寶六年一月九日	March 1, 1678.	
Hōei, 2nd „ , Dec.			8	寶永二年十二月	Jan , 1706.	
Kwanpō, 2nd „ , March 2.			9	寛保二年三月二日	April 6, 1742.	
Kwanyen, 2nd „ , Aug.	II, B. Premonitory Epoch.		10	寛延二年八月	Sept., 1749.	Eruption from the Nojiri side. The Ōhira-yama (太平山) made eruption.
Hōreki, 6th „ .			11	寶暦六年	1756.	
Meiwa, 3rd „ , April 28			12	明和三年四月廿八日（夜明）	June 5, 1766. (Daybreak)	Probably a small explosion. There were detonations and earthquakes of different intensities.
„ , „ „ , June 21.			13	同　　年六月廿一日（午後十時）	July 27, 1766. (10 p.m.)	Also probably a small explosion. There were 7 earthquakes and 9 detonations.
Anei, 8th year, Oct. 1.	II. Active Eruption Epoch. (**Anei Period**.)	Great Eruption.	14*	安永八年十月一日	Nov. 9, 1779.	Great outbursts.
„ , 9th „ , Aug. 11.		Submarine Eruption and "Tsunami."	15	同　九年八月十一日（夜半）	Sept. 9, 1780. (12 p.m.)	Submarine eruption accompanied by a small "tsunami."
„ , „ „ , Oct. 4			16	同　　年十月四日（午後十時）	Oct. 31, 1780. (10 p.m.)	*Do.*
Temmei, 1st „ , March 18.			17	天明元年三月十八日（午後四時）	April 11, 1781. (4 p.m.)	Eruption took place from (near?) the new islet (Moe-jima) off Komen, accompanied by a small "tsunami."
„ , „ „ , April 8.			18	同　　年四月八日	May 1, 1781.	
„ , „ „ , Dec. 5.			19	同　　年十二月五日（午後四時）	Jan. 18, 1782. (4 p.m.)	Submarine eruption off the coast of Komen.
Temmei, 3rd year, Aug. 7.		Smoke Emission and Ash-precipitation.	20	同　三年八月七日	Sept. 3, 1783.	
„ , 5th „ , Oct. 19.			21	同　五年十月十九日（夜半）	Nov. 20, 1785. (12 p.m.)	Small eruption from an earlier craterlet in the vicinity of Komen.
Kwansei, 2nd, „ , June 18.			22	寛政二年六月十八日（夜半）	July 29, 1790. (12 p.m.)	Detonation and ash-precipitation.
„ , 3rd, „ , Aug. 14.			23	同　三年八月十四日（午後四時）	Sept. 11, 1791. (4 p.m.)	Smoke emission and ash-precipitation.
„ , 11th „ , Feb 22.			24	同　十一年二月廿二日	March 27, 1799.	*Do.*
Manyen, 1st year.			25	萬延元年	1860	A small explosion?
Taishō, 3rd year, Jan. 12.	III. Active Eruption Epoch. (**Taishō Period**.)		26*	大正三年一月十二日	Jan. 12, 1914.	Great outbursts.

The rate of decomposition into soil of the surface portion of pumice layer is very various, being 30 to 37 cm at the Yunohama district for the duration of 135 years after the eruption of 1779, but only 13 cm at Krokami for the same time interval, and 18 cm during the long preceding interval of 303 years after the eruption in 1476.

19. Note on distribution of newer lava flows. A glance at the map of Sakura-jima shows that the extensive newer lava outflows, namely, those of the three great eruptions of 1468–1476, of 1779, and of 1914, all took place in the W. and in the S. to N.E. flanks of the volcano, there being also the promontories of Kwannon-zaki, Nagasaki-hana, and Wariishi-zaki, formed by the lava flows of older unknown dates. On the contrary, in the N.W. part of the island between Take and Shirahama, there is no craterlet and no lava outflow of comparatively new date, and from this fact it is thought possible by some people that the future outburst may occur from the same spot. Under the influence of this supposition, coupled to the earth-heat phenomena of Saido,* the inhabitants of the villages of Fujino, Saido, etc., were panic-stricken by the Kirishima earthquakes of July 14th, 1915, several of them having fled across the sea for safety.

The Bummei eruptions, 1468–1476, took place approximately along an E.N.E. and a S.W. radius, and the eruption of Anei, 1779, along a N.E. and a S. radius, while the recent eruption occurred along an E.S.E. and W.N.W. diameter through the Minami-dake crater. The line of disturbance, or craterlets axis, in the last case is, however, not a quite new one, but may be regarded as very nearly identical with the much older line of

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* Phenomena of emanation of gas and of increase of earth-temperature, which will be considered in detail in the next Number of this Volume.

Karasu-jima, Hikinohira, and Nabe-yama. In other words, the centre of eruptive activity has gone back, after a sort of shifting of radius of disturbance, in 1914 to an old site, but not to the N.W. compartment, which is thus likely not to become the scene of eruption even in future.

CHAPTER III. METEOROLOGICAL CONDITIONS AT THE TIME OF THE ERUPTION OF 1914.

20. Meteorological elements for 1913. During the 12 months preceding the eruption of Jan. 1914, the meteorological conditions at Kagoshima were abnormal in no special way. Thus, according to Tables X and XI the mean barometric pressure and air temperature in 1913 were respectively 751.7 mm and 16°.4 C, while the corresponding quantities during the 5 years, 1906–1910, were 751.4 mm and 16°.5 C. The amount of the precipitation in 1913 was, however, only 1604 mm and much smaller than the average value of 2337 mm for the 5 years interval above referred to.

21. Weather in Kagoshima at the time of eruption. At the commencement of January 1914, the weather at Kagoshima was changeful, there being in particular an unusual amount of snow-fall on the morning of the 8th. On the day of the actual eruption and during the three previous days, namely, from the 9th to the 12th, the barometer was steadily very high and ranged between 773.0 and 769.2 mm, while the wind velocity was low and varied from 2.3 to 3.5 m/sec. In fact, till 6 a.m. on the 13th, whole Japan was under an exceptionally high atmospheric pressure and the weather was calm and clear at most places, as was also characteristic of the great Sakura-jima eruption of 1779 and of the tremendous outbursts of Asama-yama in 1783. Again, on the 12th (Jan. 1914), the first powerful outbursts occurred at about 10 a.m., when the barometric pressure was at a maximum (770.1 mm). At 2 p.m., on the 13th, there appeared a centre of barometric depression of 754 mm in Yellow Sea, off the Shantung promontory, and another also of 754 mm at the mouth of the Yang-tsze, causing the pressure over Japan to fall to 770-764 mm. In consequence of this it rained in Chosen and it became cloudy over Japan; in the city of Kagoshima there being a precipitation of rain at midnight of the 12th. On the 14th, at 6 a.m., these depression centres moved across Japan Sea, and caused rain in North Kyushu, Shikoku, and the W. part of Main Island; the pressure falling to 754–761 mm over Japan, with westerly or southerly wind. Thunder storms occurred on the 14th as follows:—Between 0 and 3 a.m., in Kyushu and western portion of Main Island; at 7–8 a.m., in Shikoku, and southern part of Kii; at 2–3 p.m., in the provinces of Noto, Kai, and Musashi; and at 9–11 p.m., in Echigo and Uzen.

It might be supposed that the powerful eruptions on the 12th and 13th (Jan. 1914) had caused some increase in the air temperature about Kagoshima. But, in reality, the heating effect, whose existence is very difficult to ascertain, seems to have been quite insignificant. Thus, according to Table XIV, on the 13th the air temperature which was below 11.°1 C in the morning was suddenly increased at and after 10 a.m. to over 15°.0 C. This is, however, not to be attributed to the volcanic agency, as a similar and more abrupt change in thermometer reading took place also at Nase, in the island of Ōshima (Lyukyu), which is situated at a distance of 373 km to the S.W. of Sakura-jima, and where the air temperature was increased on the same morning from 11°.3 C at 6 a.m. to 20°.3 C at 10 a.m. The cause of the sudden temperature change was in the predominance of the southerly winds at the time in question, whose velocity was at Nase suddenly increased to 5.4 m/sec. (10 a.m.) and 12.1 m/s (2 p.m.).

Fig. 21 gives the weather map for the morning of the day of the Sakura-jima eruption, while fig. 22 illustrates the variations in the course of the daily meteorological elements at Kagoshima during the month of January, 1914.

22. Weather in Japan, Jan. 10th—20th, 1914. The following is a brief tri-daily description of the barometric distribution over Japan during the 10 days about the time of the eruption of Sakura-jima. Amongst the others the general condition of weather at 6 a.m. on the 17th was almost identical with that for the 12th (Jan. 1914), the day of the outburst.

10th, 6 a.m. Three centres of low barometric pressure of 766, 762, and 764 mm, existed over Yellow Sea, off the coast of Genzan (Chosen), and in the N. part of Japan Sea respectively. High pressure of 770–774 mm covered the central and S. portions of Japan.

10th, 2 p.m. Low centres of 762, 762, and 760 mm were in the N.E. part of Chosen, in Central Japan, and in the N. part of Japan Sea. The pressure was high (770 mm) along and off the S. coast of Honshu.

10th, 10 p.m. Low centre of 754 mm was in the S. part of Karafuto, thence increasing to 768 mm over the S. part of Japan. High pressure area of 770 mm was off the S. coast of Honshu and in E. China.

11th, 6 a.m. The pressure varied from 768 mm over Chosen and Kyushu to 752 mm at the S.E. part of Karafuto. Winds were slight and irregular in the W. half of Japan, but generally W.ly or S.W.ly in the N. half.

11th, 2 p.m. The pressure increased from 754 mm in Soya Strait to 768 mm in Kyushu and the W. part of Honshu, with a high centre of 770 mm in the N.E. part of China. Strong W.ly winds prevailed.

Fig. 21. Weather Map for Jan. 12th, 1914, 6 a.m.

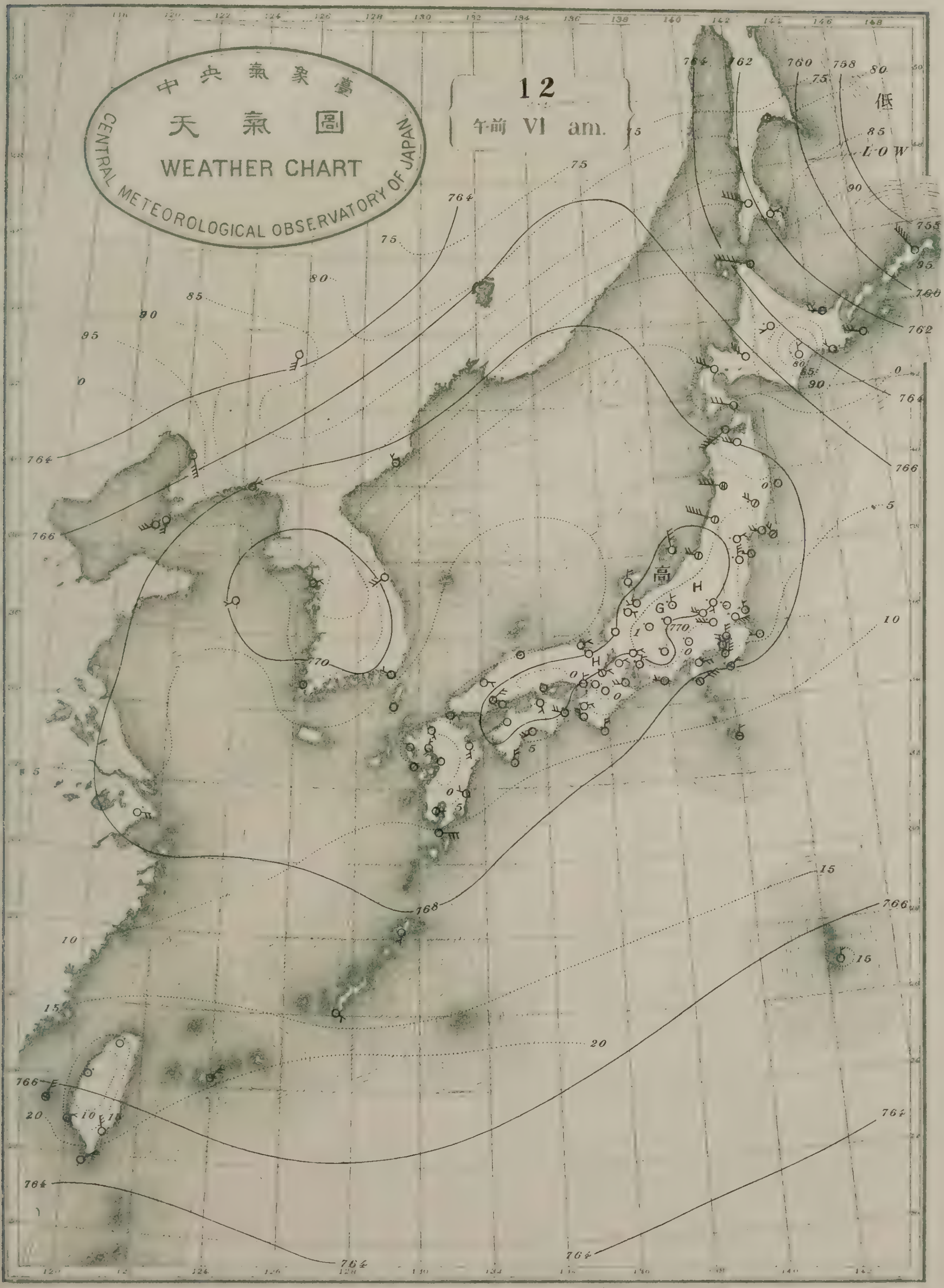

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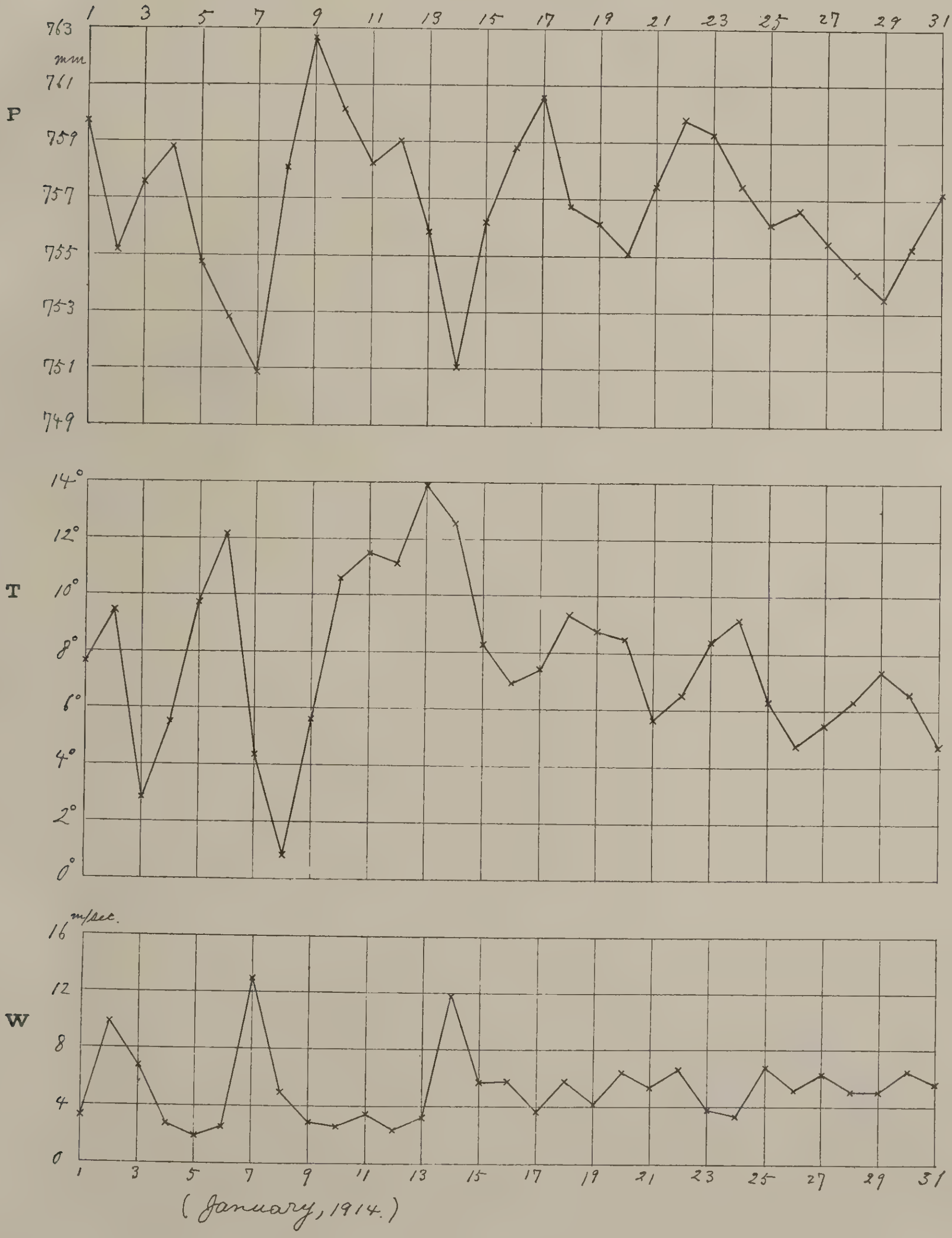
Fig. 22. Variation in the Mean Daily Barometric Pressure, Air Temperature, and Wind Velocity, during January, 1914.

P....Barometric Pressure. **T**....Air Temperature. **W**....Wind Velocity.



11th, 10 p.m. The pressure was high (770 mm) from China and Chosen to the neighbourhood of Shimonoseki, thence decreasing to 754 mm off the N.E. coast of Hokkaido. In the latter, strong W. winds prevailed, while in the rest of Japan the winds were northerly.

12th, 6 a.m. The pressure was high (770 mm) over Inland Sea, the N. part of Shikoku, and the western and central parts of Main Island. Low pressure of 764 mm was over S. Manchuria.

12th, 2 p.m. Entire Japan and the S. half of Chosen were enclosed within the isobar of 768 mm, with the centre of high pressure (770 mm) over Uzen, Ugo, and the Hokuriku provinces. Low pressure centre of 758 mm was over Manchuria.

12th, 10 p.m. Shikoku and nearly whole of Kyushu and Main Island were enclosed within the isobar of 770 mm, with the centre of maximum pressure of 772 mm over Echigo and Uzen. The centre of low pressure of 760 mm was in Manchuria.

13th, 6 a.m. Nearly the whole Shikoku and Main Island were enclosed in the isobar of 770 mm, the centre of max. pressure (772 mm) being over the central part of the latter. Low pressure centre (758 mm) was in Manchuria.

13th, 2 p.m. High pressure centre (768 mm) passed to the S.E. corner of Honshu and the adjacent sea region. Low centres of 751, 756, and 756, were respectively at the mouth of the Yang-tzse, at the Shantung promontory, and in the N. part of Japan Sea.

13th, 10 p.m. As before, the high pressure centre (764 mm) was at the S.E. corner of Honshu and to its E. Low centres of 750 and 748 mm were at the middle parts of Chosen.

14th, 6 a.m. Isobars were parallel to the Japanese islands, the pressure being 754 to 760 mm over Kyushu to Hokkaido. Two low centres of 744 and 746 mm were respectively to the E. of Genzan and off Vladivostoc, in Japan Sea. Winds were generally strong and westerly in Kyushu and Shikoku.

14th, 2 p.m. Two low centres, each of 740 mm, moved a little northwards in Japan Sea, the pressure being 760 to 744 mm over Japan, at whose S. and central parts strong W. winds prevailed.

14th, 10 p.m. Two low centres each of 736 mm passed to the N. part of Hokkaido. The pressure varied from 765 mm in Kyushu to 744 mm at Aomori. Strong W. winds prevailed over whole Japan.

15th, 6 a.m. A low centre of 736 mm existed to the N. of Hokkaido in Okhotsuk Sea, the pressure thence increasing up to 766 mm in Kyushu. Strong W. winds prevailed over whole Japan.

15th, 2 p.m. A low centre of 738 mm was at the N.E. of Hokkaido, the pressure thence increasing to 766 mm at the S.W. part of Kyushu. Strong W. winds prevailed over whole Japan.

15th, 10 p.m. A low centre of 750 mm was off the N.E. coast of Hokkaido, the pressure thence increasing to 767 mm at the S.W. part of Kyushu. Strong W. winds prevailed over whole Japan.

16th, 6 a.m. Pressure increased from 754 mm off the N.E. coast of Hokkaido to 768 mm in the W. part of Kyushu. W. winds prevailed over whole Japan.

16th, 2 p.m. There was a low pressure centre of 752 mm off the E. coast of Mutsu, while the high pressure of 772 mm extended over Yellow Sea and the E. coast of China. Strong W. winds prevailed all over Japan.

16th, 10 p.m. The pressure was high (772 mm) over China and Yellow Seas, thence decreasing to 756 mm off the N.W. coast of Hokkaido. W. winds prevailed over Japan.

17th, 6 a.m. The pressure was high (772 mm) over Kyushu, Shikoku, and in the W. and central parts of Honshu, thence decreasing to 760 mm off the N.W. coast of Hokkaido. Strong W. winds prevailed outside the high pressure area.

17th, 2 p.m. The pressure was high (772 mm) over the N.W. coast of Honshu and the adjacent sea area, and 770 to 764 mm over the greater portion of Japan.

17th, 10 p.m. The pressure was high (772–774 mm) over the central part of Honshu, and low (762 mm) to the N. of Hokkaido. A second high pressure area of 772 mm was in N.E. China. Winds were irregular and weak over Kyushu and the N. part of Honshu.

18th, 6 a.m. The pressure was high (770 mm) over the central part of

Honshu and slightly lower (766 mm) in the W. part of Japan, where it was rainy and slightly windy. A low pressure centre of 760 mm existed in the S. part of Karafuto.

18th, 2 p.m. There were two low pressure centres of 762 and 758 mm respectively off the S. coast of Kii and over the S. part of Karafuto. The pressure over Japan was from 766 mm in Kyushu to 762 mm in Hokkaido. Strong W. winds prevailed over whole Japan.

18th, 10 p.m. There were two low centres of 760 and 756 mm respectively off the E. coast of Awa-Kazusa peninsula and to the N. of Hokkaido, increasing up to 768 mm in W. Kyushu. Winds were generally westerly.

19th, 6 a.m. The pressure was high (766–767 mm) over the S.W. half of Japan, thence decreasing to 756 mm off the N.E. coast of Hokkaido. Wind was generally strong and westerly over the N. half of Japan, but it was calm or slightly windy over the other half.

19th, 2 p.m. The pressure was low (756 mm) to the N.E. of Hokkaido, thence increasing to 765 mm over the W. half of Japan. Wind was westerly nearly all over the country.

19th, 10. p.m. The pressure was high (774 mm) in the N.E. part of China, thence decreasing to 766 mm in the W. part of Kyushu and to 760 mm off the N.E. coast of Hokkaido. Over E. Kyushu, Shikoku, and Honshu, it was generally calm except at the S.E. part of the last-named island, where westerly winds prevailed.

20th, 6 a.m. The pressure was high (774 mm) over the N.E. part of China and Manchuria, thence decreasing to 762 mm off the Pacific coast of Japan. Over Japan, it was calm or there were slight westerly winds.

20th, 2 p.m. The pressure was high (776 mm) over N.E. China, thence decreasing to 760 mm off the S., S.E., and N.W. coasts of Honshu. Winds were generally westerly.

20th, 10 p.m. The pressure varied from 776 mm over N.E. China to 760 mm off the Awa-Kazusa peninsula. Over Japan, the pressure was 767 mm in W. Kyushu and 760 mm in the vicinity of Tokyo. N.W. and W. winds prevailed.

TABLE X. AVERAGE VALUES OF THE MONTHLY METEOROLOGICAL ELEMENTS AT KAGOSHIMA, 1906–1910.

Month.	Barometric Pressure.* (Reduced to 0°C.)	Air Temperature.	Precipitation.	Number of Earthquakes.
I	755.7 mm	8.1 °C	120.7 mm	5
II	754.2	6.4	101.4	2
III	753.9	10.3	150.8	5
IV	751.7	15.3	235.0	2
V	749.5	18.5	183.2	3
VI	747.1	21.9	454.7	2
VII	746.4	25.4	367.6	5
VIII	746.0	26.1	158.7	5
IX	748.8	24.1	257.6	2
X	752.4	19.2	147.9	2
XI	755.0	13.7	95.4	4
XII	756.4	8.6	61.2	3
Mean (or Sum).	751.4	16.5	2336.7 (Sum)	41 (Sum)

* Reduction to mean sea level....+11.06 mm.

TABLE XI. MEAN MONTHLY METEOROLOGICAL ELEMENTS AT KAGOSHIMA, JAN. 1913 TO MARCH 1914.

Year.	Month.	Barometric Pressure.* (Reduced to 0°C.)	Air Temperature.	Precipitation.	Number of Earthquakes.
1913	I	757.14 mm	6.84 °C.	67.8 mm	2
	II	755.36	7.19	57.4	1
	III	753.69	9.28	66.4	2
	IV	751.13	17.13	144.5	6
	V	748.93	18.50	168.6	2
	VI	746.30	21.39	476.2	19
	VII	747.11	25.08	129.3	14
	VIII	745.57	26.59	53.2	6
	IX	749.84	23.08	224.8	6
	X	751.51	19.09	37.7	7
	XI	756.56	14.09	67.8	15
	XII	756.76	8.45	110.0	11
	Mean (or Sum)	751.66	16.39	1603.7 (Sum)	91 (Sum)
1914	I	756.83	7.63	70.3	522
	II	754.74	8.85	145.3	24
	III	752.99	12.95	278.5	17

* Reduction to mean sea-level....+11.06 mm.

TABLE XII. DAILY METEOROLOGICAL ELEMENTS IN JANUARY 1914, AT KAGOSHIMA.

Day.	Air Temperature.	Barometric Pressure.*	Relative Humidity.	Wind Velocity.	Precipitation.	Evaporation.	Number of hours with Sun Shine.
	°	mm		m/sec.	mm	mm	
1	7.64C	769.96	79.3	3.20	2.1	1.6	4.47
2	9.49	765.20	72.5	9.80	7.9	3.0	2.41
3	2.81	768.00	83.4	6.87	5.6	1.0	1.19
4	5.52	769.19	68.3	2.75	—	1.5	7.89
5	9.70	764.85	88.2	1.96	5.8	0.8	1.25
6	12.12	762.80	64.8	2.54	—	—	4.30
7	4.37	761.15	73.2	13.00	7.3	0.7	1.67
8	0.81	768.60	70.8	5.05	5.8	2.4	8.75
9	5.59	773.03	63.3	3.05	—	1.6	4.23
10	10.60	770.30	81.2	2.56	6.4	1.4	0.65
11	11.49	768.29	68.1	3.50	—	2.6	7.59
12	11.10	769.17	72.5	2.32	—	3.1	7.15
13	13.94	765.69	76.4	3.21	0.3	3.2	2.15
14	12.57	760.92	65.7	11.92	16.4	4.6	5.77
15	8.25	766.42	62.3	6.00	0.1	2.6	3.17
16	6.94	769.07	67.3	5.89	0.7	2.9	4.03
17	7.40	770.84	62.8	3.64	—	2.8	0.00
18	9.38	766.87	70.8	5.80	9.2	3.8	8.07
19	8.72	766.32	61.4	4.16	—	2.6	2.65
20	8.49	765.22	66.4	6.49	0.0	3.6	5.58
21	5.66	767.72	58.8	5.40	—	3.3	6.90
22	6.55	770.02	58.0	6.68	—	3.6	0.20
23	8.41	769.52	61.4	3.85	—	2.6	6.25
24	9.15	767.59	66.3	3.34	0.0	2.3	1.91
25	6.28	766.40	66.2	6.86	2.6	3.1	8.29
26	4.72	767.01	64.7	5.24	—	3.1	7.25
27	5.45	765.77	61.4	6.40	0.0	3.3	7.09
28	6.34	764.63	60.1	4.97	0.0	3.2	7.18
29	7.35	763.70	61.6	4.95	—	3.5	8.82
30	6.55	765.59	62.0	6.44	—	4.1	9.01
31	4.70	767.58	59.9	5.61	—	3.0	6.18

* Reduced to mean sea-level and the standard gravity.

TABLE XIII. HOURLY METEOROLOGICAL ELEMENTS AT KAGOSHIMA, JAN. 10TH TO 15TH, 1914: WIND DIRECTION AND VELOCITY (m/sec.).

Day. / Hour.	10	11	12	13	14	15
1 a.m.	NNE 2.5	NNW 3.0	NE 1.9	SW 0.8	SW 6.2	NNW 8.5
2	NE 1.3	NNW 2.1	NNE 2.2	NE 0.6	SSE 7.3	NNW 7.6
3	E 2.2	N 3.4	NE 2.1	NNW 0.8	SW 8.3	NNW 6.3
4	ENE 2.4	N 4.2	SSW 0.9	N 2.3	WNW 8.2	NNW 6.5
5	NE 1.6	N 4.6	E 2.7	SW 0.7	WNW 14.5	NNW 5.9
6	E 2.2	N 4.7	ENE 3.9	SW 1.0	WNW 20.0	W 4.9
7	E 2.1	N 4.4	ENE 3.1	SE 1.2	WNW 16.1	NNW 2.0
8	E 2.4	NNW 3.4	E 3.8	SSE 1.8	W 10.4	N 3.4
9	ESE 3.1	N 1.6	ENE 3.3	NW 1.1	NNW 7.0	NNW 4.8
10	W 3.1	SE 2.9	E 3.5	SSW 0.9	W 6.8	NW 4.6
11	SSE 0.9	SW 1.4	SE 2.8	E 1.3	WNW 12.2	NW 5.5
12	SSE 2.1	NNW 2.0	SE 2.6	E 3.1	WNW 13.4	W 7.1
1 p.m.	S 2.1	NW 4.1	ESE 2.8	ESE 4.6	NNW 13.9	WNW 6.4
2	S 1.9	WNW 3.8	ESE 3.9	SSE 2.8	W 14.8	WNW 7.7
3	S 3.1	WNW 4.2	E 3.3	ESE 2.0	WNW 15.6	WNW 8.3
4	WSW 2.7	WNW 3.9	E 2.0	ESE 2.1	WNW 14.7	WNW 7.6
5	SW 3.2	WNW 3.9	E 0.5	SE 1.9	WNW 16.1	NW 5.9
6	SW 3.6	NW 4.4	ENE 0.5	S 2.2	W 15.1	NNW 4.1
7	WNW 5.8	NNW 5.1	SE 2.5	S 5.8	NNW 13.9	NNW 3.4
8	SW 3.1	N 6.6	NW 1.8	S 7.7	NW 11.8	WNW 4.0
9	SW 1.0	NE 2.5	SW 0.5	SSW 8.6	NW 10.3	NW 4.6
10	NW 1.9	ENE 1.9	SW 1.3	SSW 7.9	NW 10.9	NNW 5.3
11	NNW 3.6	E 2.8	W 2.0	SSW 8.6	NNW 9.5	NNW 4.3
12	NNW 3.6	ENE 3.1	N 1.8	SW 7.2	NNW 9.1	NNW 5.8

TABLE XIV. HOURLY METEOROLOGICAL ELEMENTS AT KAGOSHIMA, JAN. 10TH TO 14TH, 1914 : AIR TEMPERATURE AND BAROMETRIC PRESSURE.

Date. / Hour.	Air Temperature.					Barometric Pressure. (Reduced to Mean Sea-level and Standard Gravity.) 700mm +				
	10	11	12	13	14	10	11	12	13	14
1 a.m.	5°.9 C	11°.6 C	8°.1 C	10°.7 C	15°.1 C	72.5 mm	68.5 mm	69.0 mm	69.2 mm	60.1 mm
2	6.7	11.2	7.8	10.6	15.6	72.4	68.2	69.2	69.2	59.3
3	7.0	11.0	7.6	10.6	15.7	72.1	67.8	69.1	69.1	58.1
4	7.4	11.0	7.5	10.3	15.3	71.9	67.8	68.9	68.8	57.7
5	7.6	10.9	7.7	10.8	14.9	71.8	67.8	68.6	68.4	57.4
6	7.6	10.6	9.7	10.8	15.0	71.8	67.9	69.2	68.5	58.1
7	7.6	10.0	7.7	10.4	13.6	72.0	68.0	69.5	68.7	58·8
8	7.6	10.0	8.6	11.1	13.1	72.0	68.3	69.9	68.6	59.8
9	8.4	9.3	10.2	11.0	13.3	72.0	69.0	70.0	68.8	60.6
10	9.0	12.6	12.0	15.3	14.4	72.1	69.1	70.1	68.6	60.5
11	11.0	14.0	14.4	15.4	14.4	71.3	68.8	69.7	67.7	60.2
12	11.5	13.7	14.5	15.7	14.5	70.4	68.3	69.1	66.3	60.0
1 p.m.	12.3	14.4	15.3	15.4	14.2	69.6	67.9	68.3	65.3	59.6
2	13.9	15.4	15.0	16.3	14.3	69.1	67.4	68.1	65.1	59.7
3	15.0	15.0	14.6	15.7	13.7	68.7	67.3	68.2	64.7	60.3
4	15.7	14.7	13.8	16.0	12.0	68.4	67.4	68.4	64.4	61.1
5	14.4	13.3	13.8	15.6	11.7	68.7	67.8	68.8	63.8	61.8
6	14.0	11.2	12.8	15.4	10.8	68.6	68.4	69.1	63.5	62.6
7	11.5	10.0	12.2	16.1	8.0	68.8	68.6	69.5	63.1	63.5
8	11.5	9.6	11.5	16.1	8.8	69.0	68.7	69.0	62.4	63.9
9	12.2	9.4	11.6	16.3	8.7	68.8	68.9	69.6	61.3	64.2
10	12.3	9.2	11.2	16.2	8.6	68.6	69.1	69.4	60.3	64.6
11	12.5	8.8	10.3	16.7	8.1	68.4	68.9	69.7	60.3	65.0
12	11.8	8.8	10.4	16.1	7.9	68.3	69.1	69.8	60.4	65.2
Mean.	10.6	11.5	11.1	13.9	12.6	70.30	68.29	69.17	65.69	60.92

CHAPTER IV. PROPAGATION OF SOUND WAVES WHICH ACCOMPANIED THE SAKURA-JIMA OUTBURSTS OF 1914.

23. Report of Kagoshima meteorological observatory on the course of eruption. The following is a summary of the report of the Kagoshima meteorological observatory on the earlier course of the eruption at the Yokoyama, or west, side of Sakura-jima:—

On the 12th (Jan., 1914), at 8 a.m., white smokes like cloud or mist were seen ascending at the W. side of Kita-dake, while at 9.10 a.m. similar white smokes were thrown up from the top of Minami-dake. The first eruption consisted in the projection at 10. 05 a.m. of a mass of black smokes from the valley above the village of Akamizu, at an elevation of 350 to 400 m above sea-level; at 10. 10 a.m., fires were observed shooting out from the base of the smoke column, and sounds began to be heard. At 11 a.m., the black smokes ascended vertically to a height of about 3000 m, and at 10.30 a.m. the thick projection and falling down of lava fragments became visible, while the doors and shojis began to be rattled by the air shakings. At 2. 30 p.m., black and white smokes enveloped the entire island, and the eruptive sounds increased in violence, till the detonations began to be heard at 3. 30 p.m. At the severe earthquake shock of 6. 30 p.m., the burning of the mountain was further enlarged and the detonations became still more powerful. At 10 p.m., the explosive sounds were further reinforced, reaching their climax about 1 a.m., on the 13th.

On the 13th, the sounds, which gradually decreased from 6 a.m., still occurred incessantly during the day time. At 5 p.m., the wind was southerly, the right-hand side of the island becoming visible. At 8. 14 p.m., the volcanic fire-outbursts were exhibited in a grand scale and lava streams began to flow down, while red-hot rock fragments covered the mountain slope, from top to base, setting on fire the villages to the north of Hakamagoshi. The detonations occurred in continuous succession, and from the black smokes, which were thrown eastwards, lightnings flashed out in various directions. At 8. 30 p.m., the detonations ceased and the volcanic sounds became intermittent in occurrence; the shakings of the doors and shojis also ceasing.

On the 14th, after 1 a.m., the smokes were still abundant, but the sounds occurred at longer intervals. At 7 a.m., the lava streams, from which some strong explosions took place, approached to about 5 *cho* (5½ km approximately) above Hakamagoshi. The floating lava fragments, which converted the entire sea surface about the Oko-jima into a field of pumice of dark colour, drifted before noon toward the south. At 5 p.m., the fumarole phenomena from the lavas decreased to a certain degree. During the night, the activity was principally exhibited from the craterlets situated to the east of the village of Yokoyama at an elevation of 200 m above sea-level.

The precipitation of ash took place from 11.10 a.m., 12th, to 8 p.m., 13th, the amount of accumulation being 108 *momme* per *tsubo*, or 123 grams per sq. m.*

24. Barogram at Kagoshima. In fig. 24 is reproduced the barogram for Jan. 10th to 16th, 1914, obtained at the Kagoshima meteorological observatory; its diagrammatic representation being given in fig. 23. The barometric disturbance due to the eruption was very slight from the commencement at 10 a.m. till about 1 p.m., on the 12th, when an increase took place, remaining then in

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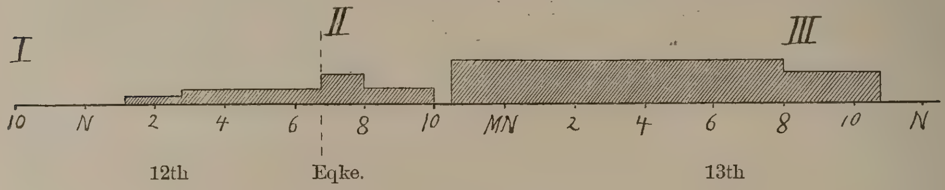
* 1 *momme*=3.76 gram; 1 *tsubo*=3.30 sq. m.

Fig. 23. Diagrammatic Representation of the Barogram obtained at Kagoshima during the Eruption (Jan. 12th and 13th, 1914).

The greater height or thickness in the diagram is intended to indicate an increased barometric disturbance



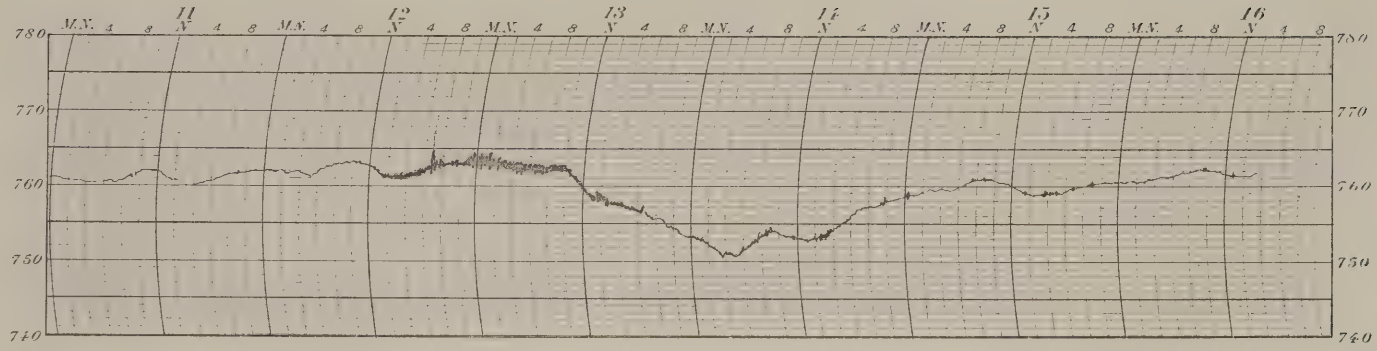
Correspondence to Sound Propagation and Ash-precipitation:

	Sound.	**Ash.**
I:	Reached to the "strong-sound zone"	Caused "mists" at distant places.
II:	Became louder. Heard in much distant places.	Precipitated as ash at distant places.
III:	Loud detonations ceased.	Became thicker in precipitation.

nearly the same condition for 9½ hours, till a little before 10 in the night of that day. Then, after nearly an hour of repose the atmospheric quakings became from 10⅔ p.m. doubly violent for nearly 12 hours, till 10½ a.m., on the 13th; the maximum activity being reached at 0 to 1½ a.m. of the latter day. Thereafter the disturbances became much reduced and smaller than in the afternoon of the preceding day, except that noted maximum groups occurred at 1 to 2⅔ p.m., 13th; about 8 to 9 a.m., and 2 to 4 p.m., 14th; and 3½ to 5 p.m., 15th. There were also single conspicuous disturbances at 6½ p.m,, 13th; 9½ p.m., 14th; 0½ a.m., 15th; 7½ and 8½ a.m., 1½, 6½, and 8⅔ p.m., 15th; and at 9 a.m. and 0½ p.m., 16th. It may be noted that the trace of the severe earthquake at 6½ p.m. on the 12th, was followed for about an hour by increased barometric vibrations, so that it is likely that the seismic shock caused, or was followed by, a temporary increase in the explosive activity.

The account of Kagoshima meteorological observatory on the course of the eruption (§ 23) is on the whole in accord with the

Fig. 24. Barogram obtained at the Kagoshima Meteorological Observatory, Jan. 11th-16th, 1914.



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indications of the barogram, which gives a faithful record of the progress of the explosive activity both of the detonative and non-detonative character.* From what has been said in § 23, I believe the highly explosive stage of the eruption to have ended at about 6 a.m. on the 13th, and been succeeded for about 4½ hours, till 10½ a.m. on the same morning, by non-detonative explosions, namely, those which threw out a great quantity of smoke and ash, without being accompanied by very loud sounds.

The maximum amount (double amplitude) of the barometric disturbance at Kagoshima was about 2½ mm, the distance of the place of observation from the principal origin of explosion, supposed to be one situated near Hikinohira on the W., or Yokoyama, side of Sakura-jima, being about 8.6 km.

25. Sound area. In fig. 25 are indicated the places affected by the sound waves due to the outbursts of Sakura-jima on Jan. 12th and 13th, 1914. The area, in which the air commotions had no audible effects, but were strong enough to shake houses or doors and shojis, extended N.E.wards to the provinces of Bizen, Mimasaka, and Bitchu, in the vicinity of the city of Okayama, and also to the Kii peninsula and the S. part of Yamato, the greatest radial extension being about 585 km. The detonative sound was heard in Kyushu (except some of its W. portions), at the S.W. end of Honshu, the W. part of Shikoku, and in a small area extending over the Kii channel; the extreme radial distance being about 500 km. The sound area was of course included in the air-shakings area, their boundaries on the W., N.W., and S.W. sides being close to each other.

A note-worthy fact is that the sound was not heard within a small E.-W. area in central Kyushu, which stretches from the central part of the province of Higo to the N.W. part of Hyuga, forming the "silence zone." (See also § 26.)

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* See the Bulletin, Vol. VII, p. 191.

26. Area in which volcanic sounds were heard earliest. In fig. 28 are indicated the places where the detonative sounds of the Sakura-jima eruption were heard between a little past 10 and 11 in the morning, or in the afternoon hours, of the 12th (Jan., 1914). It will be observed that the sounds were heard earliest in the S.E. portion of Kyushu, comprising the E. half of Satsuma, the entire province of Ōsumi, and the S. half of Hyuga, and in a zone which stretches from the head of Ariake Sea in Kyushu to the S.W. part of Shikoku, comprising the N.E. portion of Hizen, the two entire provinces of Chikugo and Bungo, the E. half of Buzen, the N. part of Higo, and a portion of Iyo. It is quite remarkable that at many places in the N. half of Hyuga, the sounds were not heard at all, while in the central and S. portion of Higo the sounds were heard only at late hours at a few places; these regions forming the "silence zone" lying between the two above-mentioned districts where the sounds were perceived earliest and loudest.

27. Relation between times of arrival of sound and of commencement of ash-precipitation. In § 24, I expressed the view that the most active stage of the detonative explosions ended at 6 a.m. on the 13th (Jan. 1914), followed for about 4½ hours by the stage of powerful non-detonative explosions, when great amount of ash must have been freely emitted from the volcano. This supposition fits well with the course of the ash-precipitation, which became thicker about 11 hours after the commencement. As assumed in § 32, the ashes first precipitated at the different distant places seem to have been thrown out from Sakura-jima at about 6 p.m. on the 12th, when the powerful detonative explosions began. We may

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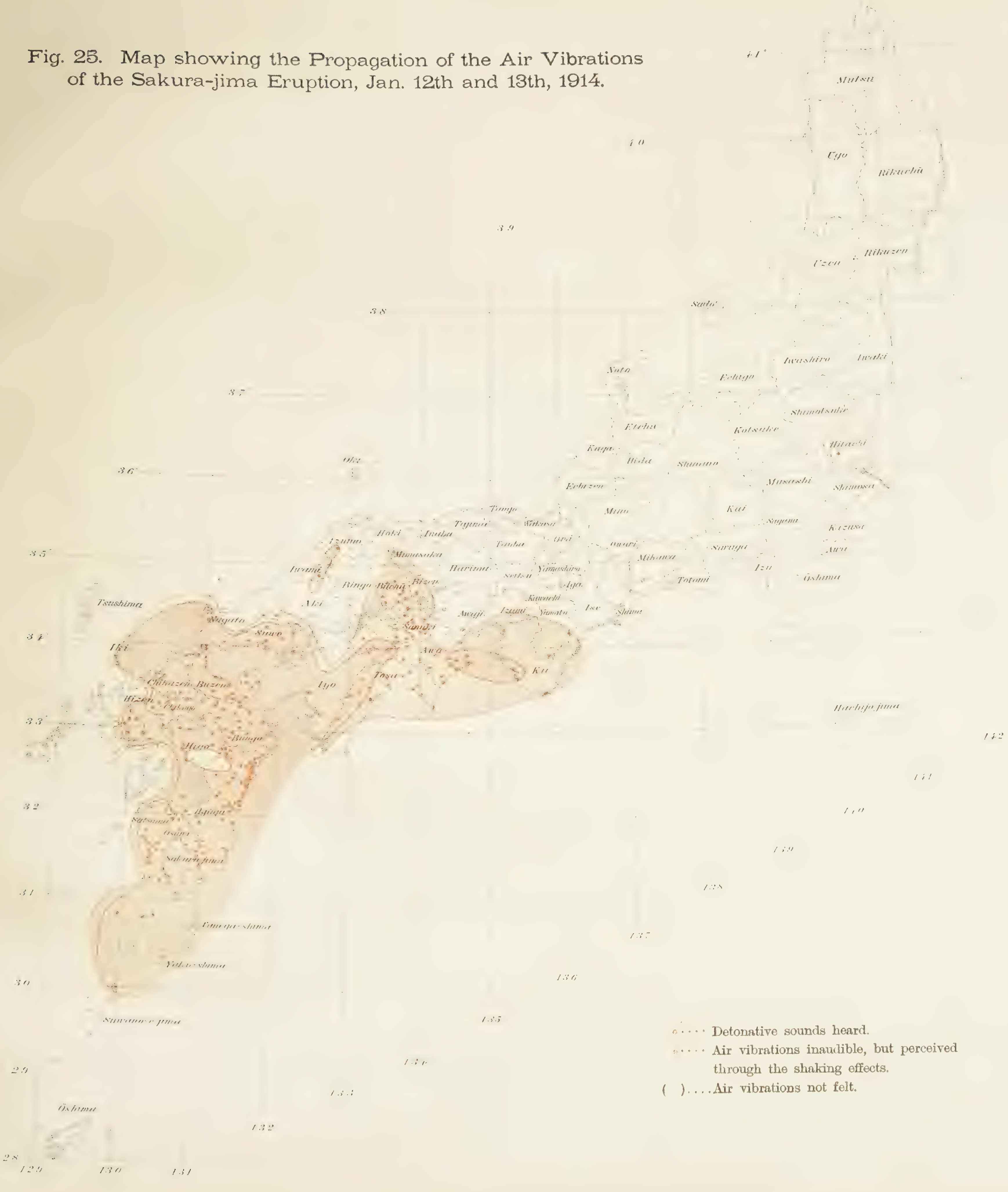
Fig. 25. Map showing the Propagation of the Air Vibrations of the Sakura-jima Eruption, Jan. 12th and 13th, 1914.



now further assume that the ashes more copiously precipitated later on to be those due to the non-detonative stage of the eruption, whose commencement was at about 11½ or 12 hours after that of the violently detonative stage. (See fig. 23.)

28. Relation between sound and ash-precipitation areas. The ash-precipitation area and the *direct propagation branch* of the sound area of a *strong* volcanic outburst tend to extend in a similar easterly direction, on account of the prevalence of westerly winds in the higher atmospheric region. In the numerous recent explosions of Asama, the ash-precipitation area was always a narrow zone, which formed in larger eruptions approximately the middle axis of the sound area. Such was also the case with the tremendous outburst of Bandai-san in 1888, and seems to be the necessary consequence of a mere powerful explosion, shattering a portion of a mountain or bursting the hardened surface of lava mass at the bottom of a crater, accompanied by the production of a comparatively small amount of volcanic dust. On the other hand, the several eruptions of Asama, which were non-detonative, often caused a notable precipitation of ash.*

In the Sakura-jima eruption of 1914, the individual explosions were not so violent as the stronger among the recent Asama-yama outbursts, while an enormous quantity of smokes and pumiceous matters were ejected simultaneously from at least half a dozen craterlets 100 to 150 m in diameter. Hence, as can easily be imagined the ash-precipitation area was much more extensive than the sound area; the greatest radius of the latter being 585 km, and that of the former not less than 1290 km.

29. Duration of volcanic sounds and air shakings at distant places, on Jan. 12th and 13th, 1914. In Table XVII is summarized the reports of different meteorological stations and other observing places at distances from Sakura-jima relating to the time of commencement and the duration of the sound and shaking effects. As will be seen from the graphical illustrations in fig. 30, the sounds became inaudible or were much weakened at the majority of places at 6 a.m. or thereabout, on the 13th (Jan.), this being the time when the loud detonations ceased to be heard in Kagoshima. With regards to the time of commencement of the sounds, there is also some correspondence among the different localities. Thus, in the distant provinces of Kii, Iyo, Tosa, and Sanuki, in Shikoku, and in the neighbourhood of Shimonoseki Strait (province of Suwo and part of Chikzen), the sounds, which were not strong, began to be heard first at about 6 p.m. on the 12th; this being the time when the detonations became louder in Kagoshima, and also at different places in the southern part of the province of Hyuga, lying at no great distance from Sakura-jima, and in the eastern part of Hizen. Again, at some places in the distant provinces of Suwo, Iyo, and Kōchi, the sounds were feeble and began at 2 to 4 p.m. (12th); this corresponding roughly to the time (about 2 p.m.) when the sounds became louder in Kagoshima, at the N.E. base of Mount Kirishima, and in the province of Bungo.

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* See the *Bulletin*, Vol. VI, Part 1, and Vol. VII, Part 1.

On the whole the sounds increased in intensity at about 2 p.m. in the eastern part of the strong-sound zone lying immediately to the N. of the silence zone (fig. 26), and then at about 6 p.m. in the S. part of Hyuga and at the W. part of the first named zone; these have corresponding phases in the Kagoshima barograph observation and mark the times when the explosive intensity of Sakura-jima was increased. The highly explosive stage of the eruption lasted for about 16 hours between 2 p.m., on the 12th, and 6 a.m., on the 13th.

30. Sounds of after-explosions. The following list gives a short account of the observation at different places of the sounds of the *after-explosions*, or small outbursts which occurred during several days following the great explosive stage of Sakura-jima eruption on the 12th and early morning of the 13th, Jan., 1914.

SOUNDS OF THE AFTER-EXPLOSIONS: TIME OF OCCURRENCE AT DIFFERENT PLACES.

MIYAZAKI PREFECTURE (Province of Hyuga):

Miyazaki meteorological observatory. 13th: 1.35–1.50 a.m.; 3.40–4.41 a.m.; 7.40–7.50 a.m.; 8.50 p.m., 3 times; 11.35 p.m. 14th: 6–7 a.m. 15th: 8.50–9.05 a.m.; 3.10 p.m.; 9.05 p.m., once; 9.40–11.30 p.m. 16th: 2.40 a.m., once, thence continued till 10.20 a.m.; 4 p.m.; 8.45 p.m., strong, once. 17th: 0.10 p.m. More or less till 20th. 21st: 8.18 a.m.; 2.30–6.00 p.m.

小林 *Kobayashi* (Nishi-Morokata County). 13th: throughout the day. 14th: throughout the day, there being a very loud detonation at 10.07 p.m. Occasional strong or feeble sounds till April.

加久藤 *Kakto.* 13th: 1.32–3.16 p.m., very loud; 5.02 p.m. 14th: 4.55 p.m. 16th till 17th, occasionally.

KAGOSHIMA PREFECTURE:

口之島 *Kuchino-shima.* Till the 19th, several times daily.

FUKUOKA PREFECTURE (Provinces of Chikzen and Chikugo):

Fukuoka met. observatory. 14th: 9.50.33 p.m., twice. 16th: 9.41.10 p.m., twice; 9.43.55 p.m., twice. 20th: 6.47.30 a.m., twice, with 2 sec. time interval.

柳川 *Yanagawa.* 11.47 a.m., 12th, till 4 a.m., 13th. 15th: 11 a.m.; 2.10 p.m.; 4.15 p.m.; 6.10 p.m.; 8.30 p.m. 19th: 1.53 p.m.; 11.50 p.m. 20th: 4.10 p.m.; 6.10 p.m.; 6.35 p.m.; 7.10 p.m.; 7.15 p.m. 24th: 3.35 p.m. 29th: 5.30 p.m.; 7.10 p.m.

福島 *Fukushima.* 14th: 10 p.m., twice.

久留米 *Kurume.* 16th: several times.

甘木 *Amaki.* 13th, 14th, 15th: several times each day. 29th: 5.40 p.m., twice.

ŌITA PREFECTURE (Province of Bungo) :

Ōita met. observatory. Till the 18th, occasionally.

日田 Hida. Till the 15th, occasionally.

SAGA PREFECTURE (Province of Hizen) :

Saga met. observatory. Till the 21st, 2 or 3 times daily.

伊萬里 *Imari.* 20th : 5.30 p.m., twice.

三養基 *Miyaki.* 14th : 0.30–1.00 p.m. 20th : 8.30 p.m.

神崎 *Kanzaki.* 13th : throughout the day. 14th : 10 p.m., loud detonation. 15th : 10 a.m., loud sounds, continuing till afternoon. 16th : 2 a.m. 20th : 1 a.m., twice.

武雄 *Takeo.* 14th : afternoon.

According to the above list, the eruptive sounds were heard mostly for about 10 days or much more at the following places :—(A), Kobayashi, Kakto, Kuchino-shima, and Miyazaki ; and (B), Yanagawa, Fukuoka, Kurume, Amaki, Saga, Kanzaki, Miyaki, Ōita, and Hida. The (A) group places, belonging to the Kagoshima and Miyazaki prefectures, are at radial distances not exceeding 83 km ; while the (B) group places, belonging to the Saga, Fukuoka, and Ōita prefectures are at radial distances varying from 177 to 223 km and are arranged along a zone parallel E.–W. nearly and across the northern part of Kyushu. The space between these groups of places, where volcanic sounds were not heard (at least, not reported) after the 12th and 13th (Jan. 1914), forms the usual *silence zone.* (See fig. 27.) It will be seen that the map is very similar to that (fig. 26) showing the distribution of the places where the detonation was heard very loudly on Jan. 12th, 1914.

Some of the sounds due to the explosions between the 13th and 16th, Jan. 1914, were very loud at Kanzaki (Hizen), and at Miyazaki, Kakto, and Kobayashi (Hyuga). Amongst the others, the detonation at about 10 p.m., on the 14th, was heard at Fukuoka, Fukushima, Kanzaki, and Kobayashi.

At Fukuoka and Amaki in Chikzen, and Imari and Kanzaki in Hizen, the volcanic detonation was generally composed of two sounds with a time interval probably of some 2 sec. This seems to be a phenomenon similar to what took place in the propagation of strong sound waves from the crater of Asama-yama.*

31. Propagation of strong detonative sounds. The air disturbances caused by the outbursts of Sakura-jima were perceived as loud sounds in the E. portion of Satsuma, nearly the whole of Ōsumi, the S. half and the N.E. corner of Hyuga, the whole of Chikugo, nearly the whole of Bungo, the N. portion of Higo, the E. portion of Buzen, and the N.E. portion of Hizen, and at a number of places in the three Shikoku provinces of Tosa, Awa, and Iyo. As will be seen from Table XVII, the sounds were there in great many cases like gun boomings or thunder peals, accompanied by strong shakings of houses, doors, and shojis. With the exception of the Shikoku provinces, the first arrival of the perceptible air vibrations in these districts was generally in the fore-noon of the 12th (Jan. 1914).

As will be seen from the map (fig. 26), the sound waves of the eruption was perceived with great intensity in the following two districts :—(A), a semi-circular area occupying the S.E. portion of Kyushu, namely, the eastern portion of Satsuma, the whole of Ōsumi except its southern end, and the S. half of Hyuga; (B), an irregular arc or zone across the N. portion of Kyushu in an E.W. direction, namely, the whole of Bungo and Chikugo, the N.E. corner of Hyuga, the S.E. portion of Buzen, the N. portion of Higo, and the E. portion of Hizen. The formation of the (A) area is due to the direct eastward sound propagation from Sakura-jima, while the (B) area is separated from the other by the silence zone, including the S. portion of Hizen, the central and S. portions of Higo, and the N. portion of Hyuga. At several places in the (B) area, the detonations were extremely loud.

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* See the Bulletin, Vol. VI, p. 75.

32. Arrival of volcanic sound waves at different places. Table XIX gives, with respect to the Sakura-jima outbursts on Jan. 12th and 13th, a comparison of the times of the first arrival at different places of the air concussions or vibrations, namely, of either the detonative sounds or the inaudible aerial waves causing shaking effects.

The comparison of the distribution of the time of the sound arrival in Kagoshima prefecture (provinces of Satsuma and Ōsumi) with those in all the other prefectures noted in Table XIX is as follows :—

TABLE XV. TIME OF FIRST SOUND ARRIVAL AT DIFFERENT PLACES IN KAGOSHIMA PREFECTURE COMPARED WITH THOSE FOR OTHER PREFECTURES.

Kagoshima Prefecture.		Other Prefectures.	
Time of Commencement.	Number of Places.	Time of Commencement.	Number of Places.
10–10⅔ a.m.	52	10–10½ a.m.	20
11–11½ a.m.	3	11–12 a.m.	16
		1 p.m.	6
2 p.m.	3	2 p.m.	3
3 p.m.	1	3 p.m.	3
		4–4½ p.m.	11
		5–5⅓ p.m.	8
6–6½ p.m.	8	6–6⅚ p.m.	17
		7–7½ p.m.	5
		8 p.m.	1
		9 p.m.	2
		10 p.m.	1
		12 p.m.	1

From Tables XVIII and XIX, it will be seen that the air vibrations began to arrive, (i), for a great majority of places at 10 to 10½ a.m.; and in the next instance, (ii), at about 6 p.m., on the 12th. The first of these two epochs corresponds of course to the commencement or earlier part of the eruption, while the second probably marks the time when the latter entered on the more explosive stage. Naturally the sounds were heard at the earlier epoch (i) at several places in the Kagoshima and Miyazaki prefectures near the volcano. This was, however, also the case to a notable extent in the Ōita, Fukuoka, Kumamoto, and Saga prefectures (provinces of Bungo, Buzen, Chikzen, Chikugo, and Hizen, and the N. part of Higo), which is separated by the *silence zone* from the neighbourhood of Sakura-jima. (See §§ 30 and 31.) The sound waves arrived at the later epoch (ii) at places further distant from the volcano, in the prefectures of Kōchi (Tosa), Yamaguchi (Suwo and Nagato), Okayama (Bizen, Bitchu, Bingo, and Mimasaka), etc. In the Nagasaki prefecture (Hizen), which is situated to the N.W. from Sakura-jima, the air waves were perceived also at the (ii) epoch.

33. Remarks on sound areas. What has been stated in §§ 25, 26, 30, and 31, with regards to the propagation of the eruptive sounds in their different aspects, is summarized in the following table, in which (A) is the area of direct sound propagation, or that including the volcano itself, and (B) the detached sound area situated to the north of the silence zone and extending nearly in an E.W. direction.

TABLE XVI. SOUND-AREAS AND SILENCE ZONE OF THE SAKURA-JIMA ERUPTION, 1914.

Sound Area. (R=Radial Distance)	Strong sound. (Fig. 26.)	Sounds of after-eruptions. (Fig. 27.)	Earlier sound propagation. (Fig. 28.)	Mean.	General sound propagation. (Fig. 25.)
A Area.					
R, max. (N.E.)	114 km	102 km	111 km	110 km	— km
B Area.					
Inner boundary: R, max.	153	186	158	166	—
" R, min.	139	158	140	146	114
" R, mean.	152	173	144	156	—
Outer boundary: R, max.	247	230	248 (N.); 373 (N.E.)	—	140
" R, min.	195	210	200	202	—
" R, mean.	215	225	—	220	—
Central line: R, mean.	177	196	195	**190**	—
Width, max.	107	—	112	110	—
" mean.	68	64	93	75	—
Silence Zone.					
Central line: R, (N.E.).	135	116	135	129	—
" R. (N.).	104	—	105	105	—
" R, (N.N.W.).	—	128	—	—	—
" R, mean.	....	....	....	....	**127**
Width: E. part.	51	108	44	—	—
" Central part.	—	108	—	—	26

From the above table we see that the extensions and distances of the propagation areas remained nearly alike in the three cases of the strong detonation, and of the sounds of the after-explosions and of the earlier portion of the main eruption (figs. 26, 27, and 28). Thus, the maximum radius of the (A) area, in the N.E. direction, had the mean length of 110 km, while the mean radii of the inner and outer boundaries of the more or less arcual (B) area were respectively about 156 and 220 km, with the mean width, or N.S. dimension, of about 75 km. It is interesting that

Fig. 26. Map of Kyushu, indicating the Propagation of the Strong Detonative Sounds.

(●)....Loud sounds heard.

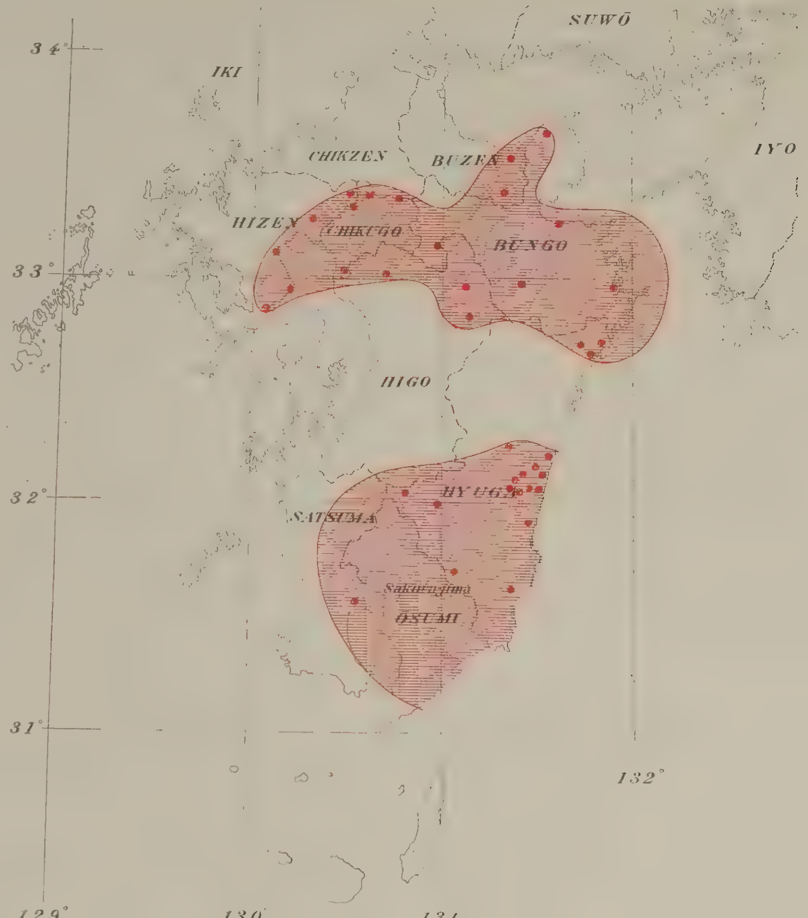
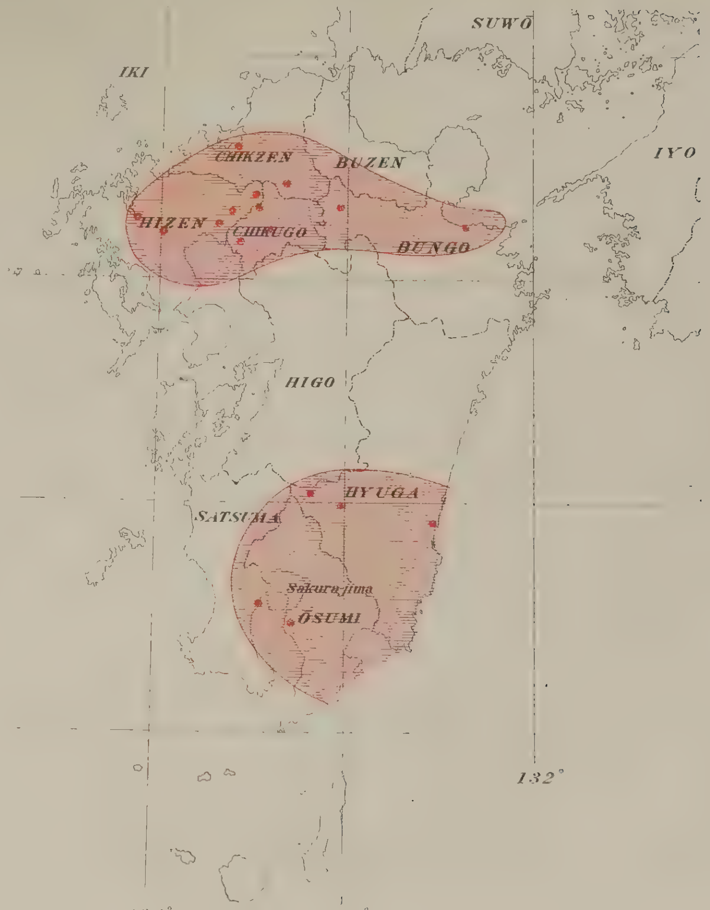
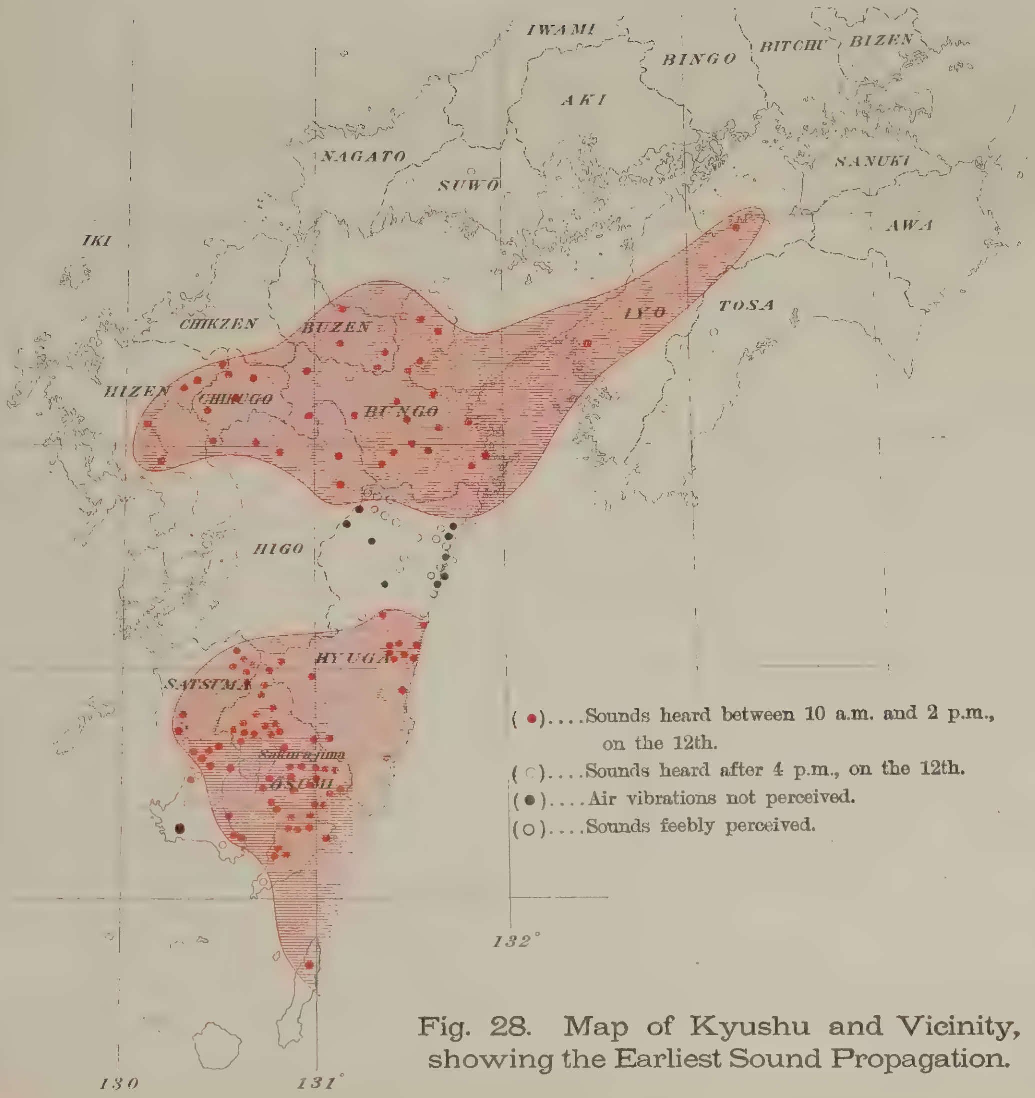


Fig. 27. Map of Kyushu, indicating the Propagation of the Sounds of the After-eruptions.

(●)....Sounds heard on or after Jan. 14, 1914.





(●)....Sounds heard between 10 a.m. and 2 p.m., on the 12th.

(○)....Sounds heard after 4 p.m., on the 12th.

(●)....Air vibrations not perceived.

(○)....Sounds feebly perceived.

Fig. 28. Map of Kyushu and Vicinity, showing the Earliest Sound Propagation.

Fig. 29. Map of Kyushu, indicating the Area of Ash-Precipitation on Jan. 17th, 1914.

(•)....Place where the ash-precipitation took place.

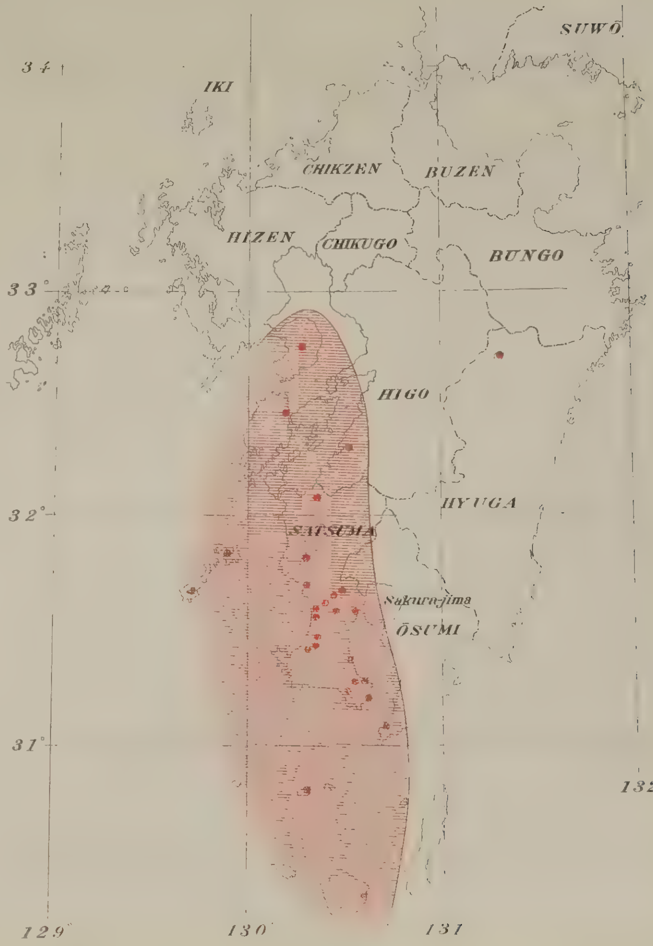


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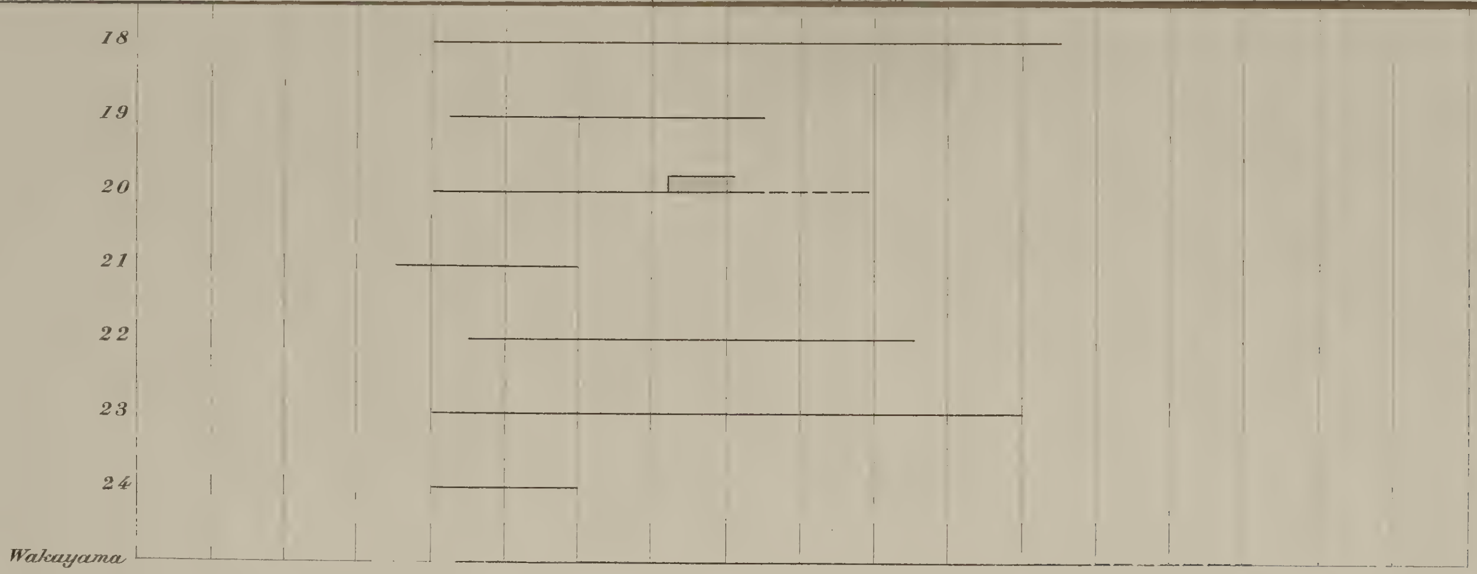
Fig. 30. Diagrammatic Representation of the Times of Arrival of the Successive Sound Phases at different places.

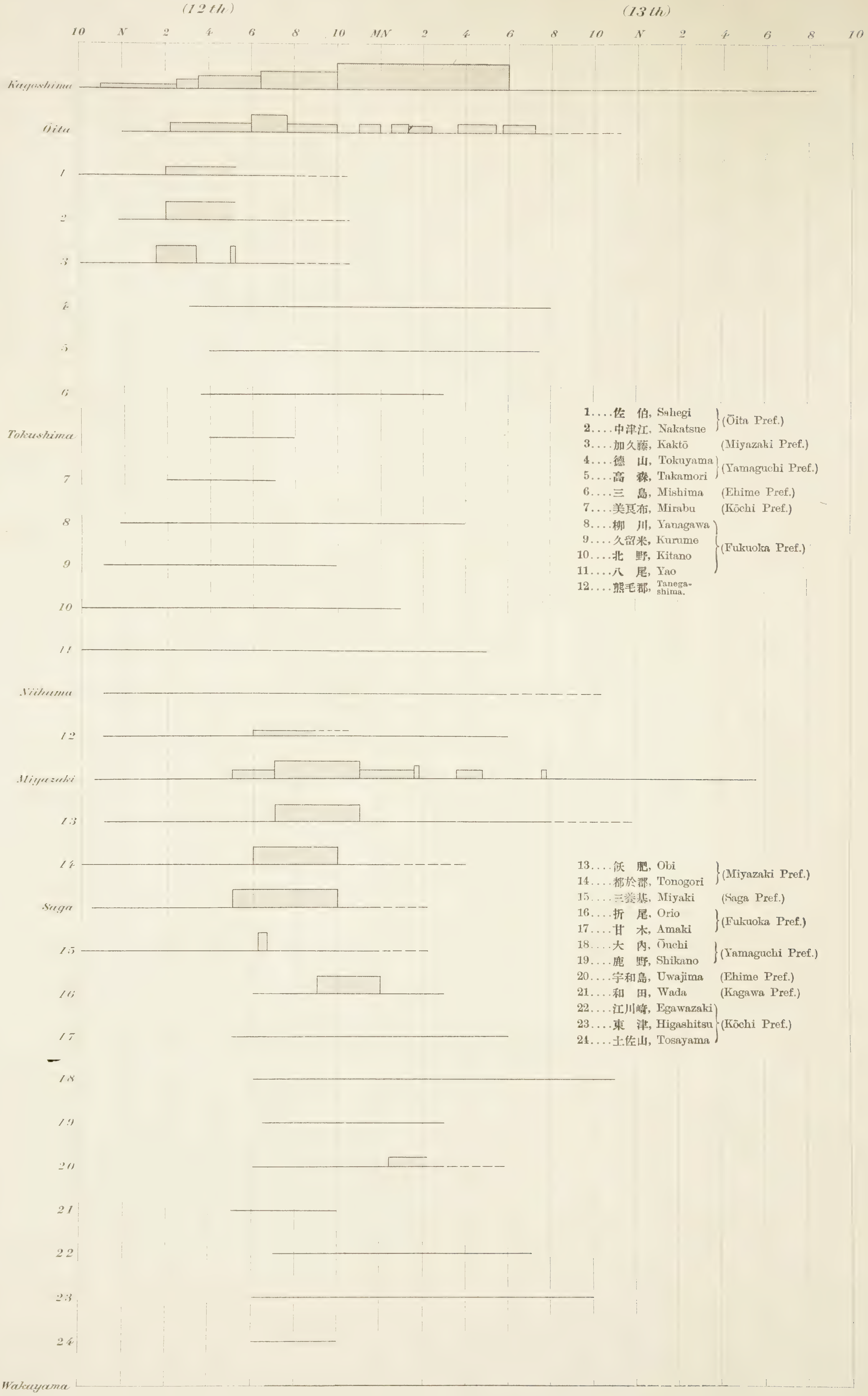
(Jan. 12th and 13th, 1914.)



(In each diagram, the greater height or thickness is intended to indicate an increased sound intensity.)

Fig. 30. Diagrammatic Representation of the Times of Arrival of the Successive Sound Phases at different places.

(Jan. 12th and 13th, 1914.)



(In each diagram, the greater height or thickness is intended to indicate an increased sound intensity.)

the average value of the radius of the middle point in the (B) zonal area is 190 km and practically identical with the result obtained for the case of the Asama-yama explosions, in which the centre of the detached sound area was westwards at a distance of 186 km from the volcano. (See the Bulletin, Vol. VII, fig. 43.)

The width of the silence zone was, as may be expected, great and equal to about 108 km in the case of the comparatively feeble sounds of the after-explosions; being much smaller, and about 40 to 50 km, in the case of the stronger sounds. Yet the middle axis of the silence zone was at a nearly constant radial distance of about 120 km; this being again approximately equal to the mean distance for the case of the general sound propagation during the first two days of the eruption, (fig. 25), in which the silence zone was reduced to a very small space, of inner and outer radii respectively of 114 and 140 km, (with the width of only 26 km, and the length of 65 km), the centre being at a distance of 127 km from Sakura-jima.

TABLE XVII. DURATION OF VOLCANIC DETONATIONS AT DIFFERENT PLACES.

(The time relates, if not otherwise mentioned, to the 12th of Jan., 1914.)

Prefecture. (Province).	Place.	Occurrence of Sounds and Air Shakings.
Miyazaki. (Hyuga.)	Miyazaki Met. Observatory.	Sounds like distant thunders, (with very slight shaking effects), from 10.30 a.m., thence gradually increasing. Air shakings stronger since 5 p.m., 12th, maximum in force at 10.20–11.05 p.m., thence slightly decreasing. (The sounds remained in the mean-while nearly constant in intensity.) Stronger again at 1.35–1.50; 3.40–4.51; 7.40–7.50 a.m., 13th; thereafter feebler.
	Miyazaki county office.	Sounds, from 10.40 a.m., strongest at 7–10 p.m., 12th; declining from 6 p.m., 13th.
	飫肥 Obi.	Sounds, from 11 a.m., strongest at 7–11 p.m.

TABLE XVII. (*Cont.*)

Prefecture. (Province.)	Place.	Occurrence of Sounds and Air Shakings.
Miyazaki. (Hyuga.)	加久藤 Kakto.	Sounds, from 10.03 a.m.; strong and like boomings of guns in battle, with air shakings, from 1.32 to 3.16 p.m., also at 5.02 p.m.
	都於郡 Tonogori.	Sounds, from 10 a.m., stronger after 6 p.m. Air shakings, from 1 p.m.; very strong from 6 p.m.
Ōita. (Bungo.)	Ōita Met. Observatory.	Sounds: from noon, like distant thunders; from 2.10 p.m., like boomings of guns (with strong shakings); strongest at 6–7½ p.m., thence lessening in intensity. Between 11 and 12 p.m., 5 or 6 detonations. 0.30–1.10 a.m. (13th), quiet; 1.10–2.20 a.m., some weaker sounds; 3.40–5.20 a.m., stronger again; 5.45–7.10 a.m., very strong, thereafter weakening.
	佐 伯 Sahegi.	10 a.m., strong shakings; 2 p.m., sounds like boomings of guns.
	中津江 Nakatsuye.	11.50 a.m., sounds like boomings of guns; 2 p.m., very strong.
Kumamoto. (Higo.)	Kumamoto Met. Observatory.	4.25–30 p.m., faint sounds like distant thunders.
Saga. (Hizen.)	Saga Met. Observatory.	From morning, sounds like gun boomings; 5–10 p.m., stronger.
	三養基 Miyaki.	Sounds, from 10 a.m., strongest at 6.10–6.30 p.m.
Kagoshima. (Satsuma.)	Tanega-shima.	Sounds like gun boomings, accompanied by shakings, began at 11 a.m. and increased in force toward the evening, continuing till 6 a.m., 13th.
Fukuoka. (Chikzen, Chikugo, Buzen.)	柳 川 Yanagawa.	Sounds, from 11.47 a.m. to 7 p.m.; more or less till 4 a.m., 13th.
	大牟田 Omuta.	Sounds at 11 a.m.; stronger from 4 p.m., with shakings.
	久留米 Kurume.	Sounds, from 11 a.m. to 10 p.m.
	北 野 Kitano.	Sounds, from 10 a.m. to 1 a.m., 13th.
	甘 木 Amaki.	Sounds, from 5 p.m. (12th) to 6 a.m., 13th.
	東 郷 Togo.	Sounds, from 9 p.m. (12th) to 1 a.m., 13th.
	折 尾 Orio.	Sounds from 6 p.m.; strongest from 9 to 12 p.m.; continued till 3 a.m., 13th.
	八 屋 Hachiya.	Sounds, from 10 a.m. to 4 p.m.; also from 5 p.m. (12th) to 5 a.m., 13th.

TABLE XVII. (*Cont.*)

Prefecture. (Province.)	Place.	Occurrence of Sounds and Air Shakings.
Kōchi. (Tosa.)	江川崎村字下山 Shimoyama.	Sounds, from 7 p.m. (12th) to 7 a.m., 13th.
	東津野村芳生野 Yoshibuno.	Sounds, from 6 p.m. (12th) to 10 a.m., 13th.
	土佐山村桑尾 Kuwao.	Sounds, 6–10 p.m.
	美良布村上野尻 Kaminojiri.	Sounds, 2–7 p.m.
Ehime. (Iyo.)	Niihama Met. Observatory.	Sounds like gun boomings, from a little before noon till evening. Shojis shaken till morning, 13th.
	宇摩郡三島 Mishima.	Slight shakings, from 3.40 p.m. till 3 a.m., 13th.
	八幡濱 Yawatahama.	Sounds, from 6 p.m., strongest at 0.20 a.m., 13th.
Kagawa. (Sanuki.)	和田 Wada.	Shakings, from 5 to 10 p.m.
Yamaguchi. (Nagato, Suwo.)	大内村 Ōuchi.	Sounds, from 6 p.m. (12th) to 11 a.m., 13th.
	德山 Tokuyama.	„ „ 3 p.m. (12th) to 8 a.m., 13th.
	高森 Takamori.	„ „ 4 p.m. (12th) to 7½ a.m., 13th.
	鹿野 Shikano.	„ „ 6½ p.m. (12th) to 3 a.m., 13th.
Tokushima. (Awa.)	Tokushima Met. Observatory.	Sounds, with shakings, 4–8 p.m.
Wakayama. (Kii.)	Wakayama Met. Observatory.	Sounds, from 6½ p.m. to 13th, afternoon.

TABLE XVIII. LIST OF PLACES WHERE ON JAN. 12TH, 1914, STRONG VOLCANIC DETONATIONS WERE OBSERVED.*

(The time relates, if not otherwise mentioned, to the 12th of Jan., 1914.)

Place.	Time of Commencement of Detonations.	Intensity of Detonations.
Miyazaki Prefecture. (Province of Hyuga.)		
都之城 Miyakonojō.	10 a.m.	Loud, shaking doors and shojis very much.
小林 Kobayashi.	10 a.m.	Very strong.
高鍋 Takanabe.	Noon.	Like boomings of guns, shaking doors and shojis.

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* In the Kagoshima prefecture, the sounds were loud in the E. portion of Satsuma and in nearly the whole of Ōsumi.

TABLE XVIII. (*Cont.*)

Place.	Time of Commencement of Detonations.	Intensity of Detonations.
Miyazaki Prefecture. (Province of Hyuga.)		
富田村 Tonda.	—	Strong, with much shakings.
新田村 Niuda.	—	*Do.*
都於郡村 Tonogōri.	10 a.m.	Stronger after 6 p.m., and accompanied by air shakings after 1 p.m.
三財村 Sanzai.	—	Very violent and like thunders; shakings also very strong.
三納村 Minō.	—	Violent, air shakings also being excessive as to render habitation in houses with glass windows dangerous.
川南村 Kawanami.	—	Strong, like distant thunders.
東米良村 Higashi-mera.	—	*Do.*
木城村 Kijō.	—	Strong, with shakings.
上穂北村 Kami-Hokita.	—	*Do.*
北川村 Kitagawa.	—	Strong, with much shakings.
南浦村 Minami-Ura.	2 p.m.	Violent.
北浦村 Kita-Ura.	—	Strong.
宮崎町 Miyazaki.	—	*Do.*
飫肥町 Obi.	11 a.m.	Violent.
加久藤 Kakto.	—	Very strong and like gun boomings in battle.
Ōita Prefecture. (Province of Bungo.)		
大分町 Ōita.	Noon.	Strong, like boomings of guns, with excessive shakings.
佐伯町 Sahegi.	10 a.m.	Began with strong shakings; sounds like boomings of guns, from 2 p.m.
三重村 Miye.	10 a.m.	Like boomings of guns, with very strong shakings.
竹田村 Takeda.	10 a.m.	*Do.*
中津江村 Nakatsuye.	11.50 a.m.	Like boomings of guns, with violent shakings.
津房村 Tsubusa.	—	Very strong in the afternoon.
四日市村 Yokkaichi.	—	Strong from 1 p.m.
東都甲村 Higashi-Togo.	Forenoon.	Excessively strong in the night.

TABLE XVIII. *(Cont.)*

Place.		Time of Commencement of Detonations.	Intensity of Detonations.
Kumamoto Prefecture. (Province of Higo.)			
高 森	Takamori.	Noon.	Like boomings of distant guns. Some doors and shojis were overthrown.
宮 地	Miyazi.	—	Detonations were excessive.
山 鹿	Yamaga.	10 a.m.	Like boomings of guns.
Saga Prefecture. (Province of Hizen.)			
三養基	Miyaki.	10 a.m.	Violent, like boomings of guns or distant thunders.
藤 津	Fujizu.	8 a.m.	From 6–7 p.m. the sounds became louder, and like the reports of guns fired at some distance. Heard toward S.E.
佐 賀	Saga.	Morning.	Like boomings of guns, accompanied by shakings; strongest at 5 p.m. Heard toward S.E.
Nagasaki Prefecture. (Province of Hizen.)			
小長井	Konagai.	10 a.m.	Excessively strong, and like boomings of guns; accompanied by shakings. Heard toward S.
諫 早	Isahaya.	—	Strong, like distant thunders. Heard toward S.
Fukuoka Prefecture. (Province of Chikzen, Chikugo, Buzen.)			
大牟田	Ōmuta.	11 a.m.	Like distant thunders, with shakings; strong from 4 p.m.
久留米	Kurume.	11 a.m.	Very loud in the afternoon.
北 野	Kitano.	10 a.m.	Like boomings of guns; shakings became violent from 5–6 p.m., 13th.
吉 井	Yoshii.	5 p.m.	Very strong after 3 p.m., 13th.
折 尾	Orio.	6 p.m.	Like boomings of guns; very strong from 9 to 12 p.m.
八 屋	Hachiya.	10 a.m.	Strong, with slight shakings.
Kōchi Prefecture. (Province of Tosa.)			
江川崎村字下山	Shimoyama.	7 p m.	Rolling sounds continued throughout the night.
大野見村字吉野	Yoshino.	3 p.m.	Shakings strongest at 5 a.m., 13th.
地 藏 寺	Zizoji.	—	Shakings strong at 6 p.m., 13th.
Tokushima Prefecture. (Province of Awa.)			
日野谷	Hinoya.	Afternoon.	Shook as in a strong earthquake.

TABLE XVIII. (*Cont.*)

Place.		Time of Commencement of Detonations.	Intensity of Detonations.
Yehime Prefecture. (Province of Iyo.)			
宇和島	Uwajima.	6 p.m.	Like boomings of guns, shaking shojis slightly. Very strong after midnight.
八幡濱	Yawatahama.	6 p.m.	Loud detonations, causing slight shakings; heard toward S.W.

TABLE XIX. SOUNDS OF SAKURA-JIMA ERUPTIONS OBSERVED AT DIFFERENT PLACES.

(The time relates, unless otherwise mentioned, to the 12th of Jan., 1914.)

Prefecture. (Province.)	Time of Comm't	No. of Places.	Time of Comm't	No. of Places.	Time of Comm't	No. of Places.
Kagoshima. (Satsuma, Ōsumi.)	10–10⅔ a.m. 11–11½ a.m.	52 3	2 p.m. 3 p.m.	3 1	6–6½ p.m.	8
Miyazaki. (Hyuga.)	10½–11 a.m.	5	—		—	
Ōita. (Bungo.)	10–12 a.m.	21	1–2 p.m. 3 p.m.	2 2	4 p.m.	2
Kumamoto. (Higo.)	10–12 a.m.	4	—		4½–7 p.m.	5
Saga. (Hizen.)	8–10 a.m.	2	2 p.m.	1	5–6 p.m.	2
Nagasaki. (Hizen.)	10 a.m.	1	—		4–6 p.m.	4
Fukuoka. (Chikzen, Chikugo, Buzen.)	11 a.m.	6	1–2 p.m.	2	5–7 p.m. 9–11 p.m.	5 3
Yehime. (Iyo.)	11½ a.m.	1	3 p.m.	1	6 p.m.	1
Kōchi. (Tosa.)	—		2 p.m.	1	4–5 p.m. 6 p.m. 7–9 p.m.	2 3 3
Kagawa. (Sanuki.)	—		1 p.m.	2	5 p.m.	1
Yamaguchi. (Suwo, Nagato.)	—		1–3 p.m.	2	4½–7 p.m. 0–3 a.m. (13th)	5 3
Nara. (Yamato.)	—		0⅔ p.m.	1	6⅚ p.m.	1
Okayama. (Bizen, Bitchu, and Mimasaka.)	—		—		4–6 p.m. 10 p.m.	5 1
Shimane. (Iwami, Izumo, Oki.)	—		—		6 p.m.	1
Tokushima. (Awa.)	—		—		4 p.m.	1
Wakayama. (Kii.)	—		—		6½ p.m.	1

CHAPTER V. ACCUMULATION AND TRANSPORTATION OF ASHES THROWN OUT DURING THE SAKURA-JIMA ERUPTIONS OF 1914.

34. Emission of ashes from two craterlets groups. The eruptive, especially the explosive, energy of the eastern, or Nabe-yama, side craterlets group was much more powerful than that of the western, or Yokoyama, side one. Thus, for instance, on the latter side only one of the explosive vents is large, while there are on the former four large explosive craterlets, beside a large *eruption crack* formed across the shoulder of Nabe-yama. The volume of lava outflow from the eastern craterlets was also more than double that from the western ones. From these facts it may be concluded that the pumice and ash, which were carried by the winds mainly eastwards, originated at least twice as much from the former than from the latter craterlets group.

35. Distribution of ash and pumice in Sakura-jima. The greatest precipitation of ash and pumice was in the vicinity of Nabe-yama, the thickness of the accumulation being about 4 metres in the valley between the latter and Gongen-yama (a 340-metre hill), and from 1.8 to 2.2 m in the low districts about the village of Krokami. To the S.E., on the top of the 325-metre Sakkabira (Hayasaki) promontory at the opposite side of the former Seto strait, the precipitation was reduced to 69 cm. To the N.E., on the slope of Kita-dake, above Komen at 400 m height, the thickness of the pumice layer was 90 cm, being not less than 1 m on the peak summit itself. On the other hand, the top of Minami-dake was thinly covered by pumice, at least at the S.E. part of the crater rim, where black earth remained exposed at some places.

The Kamano trigonometrical point on the 374 m hill above the villages of Take, Fujino, and Saido, was covered by ash and pumice to a thickness of 1.35 m.

The pumice pieces precipitated during the active epoch of the eruption were larger than those at succeeding times, and the surface ashes which cover the pumice layers were due to the subsequent weaker outbursts. The following supplementary list of the ash and pumice accumulations at different places in Sakura-jima is taken from the report of the Forest Office of Kagoshima respecting the effects of the eruption on forestry.

TABLE XX. ACCUMULATION OF ASH AND PUMICE IN SAKURA-JIMA.

(1 *sun*=1.2 inch=30.3 mm.)

Locality.	Surface Ash-layer.	Pumice Layer.		
		Upper portion. (Fine pumice.)	Lower portion. (Coarse pumice.)	Total Thickness.
	sun	*sun*	*sun*	*sun*
Yunohama (湯之濱), at 150 m height.	2.5	1.9	3.1	5.0
Between Yunohama and Furusato, at 150 m height.	2.5	—	—	3.7
Above Yunohama, at 250 m. height.	3.0	—	—	6.0
Cultivated field at the east of Furusato.	2.5	—	—	3.7
Above Furusato, at 140 m height.	2.5	—	—	2.5
Yunohama beach.	3.7	—	—	0.0
Above Kwannon-zaki.	2.5	—	—	0.0
At Kwannon-zaki.	1.9	—	—	0.0
Between Furusato and Yuno (湯之).	1.9	—	—	0.0
At Yuno and Mochiki (持木).	1.7	—	—	0.0
Krokami (黑神).	2.0—3.0	—	—	40.0—70.0
Vicinity of Gongen-yama, near Krokami.	—	—	—	>35.0
At Uranomae (浦ノ前).	6.0	5.0	5.0	10.0
Near Komen, at 150 m height.	1.3	—	—	13.0
Cultivated field at Shirahama (白濱).	0.6	—	—	13.0
" " above Matsuura (松浦).	0.5	—	—	18.0
Saido (西道).	1.2	—	—	18.8
Cultivated field above Saido.	(Slight)	—	—	24.0
" " at Fujino.	"	—	—	18.0
Near Take (武), at 100 m height.	"	—	—	18.0

sh accumulation.)
lines of
ively.

Pl. XXIV.

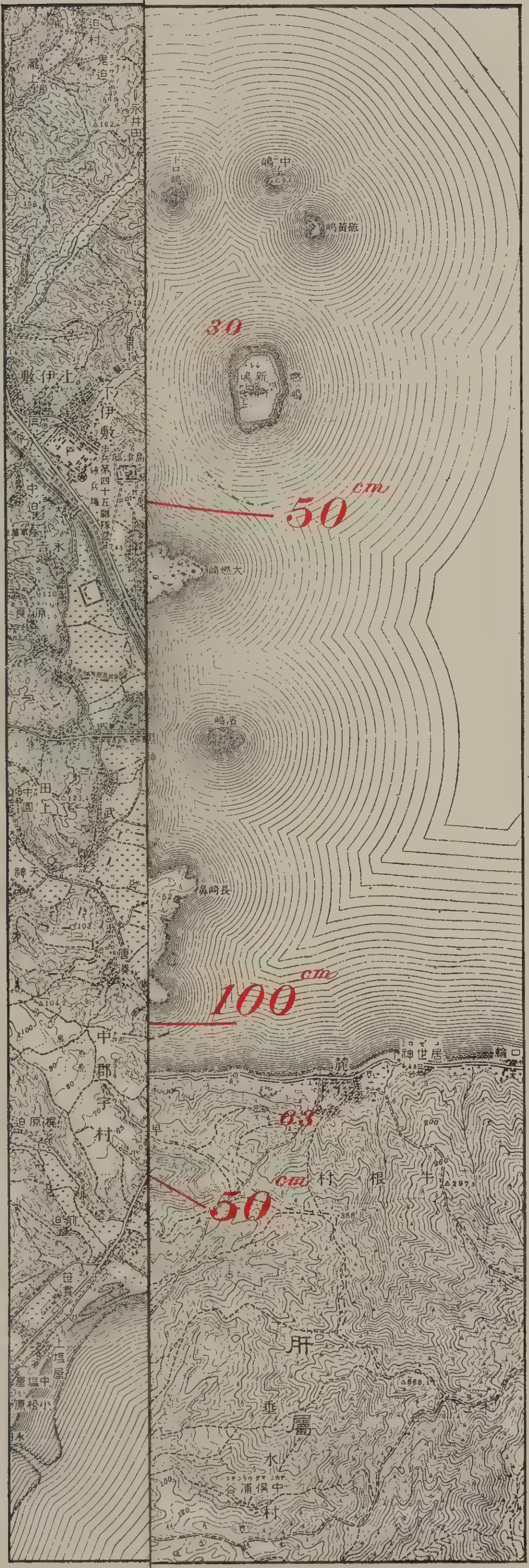

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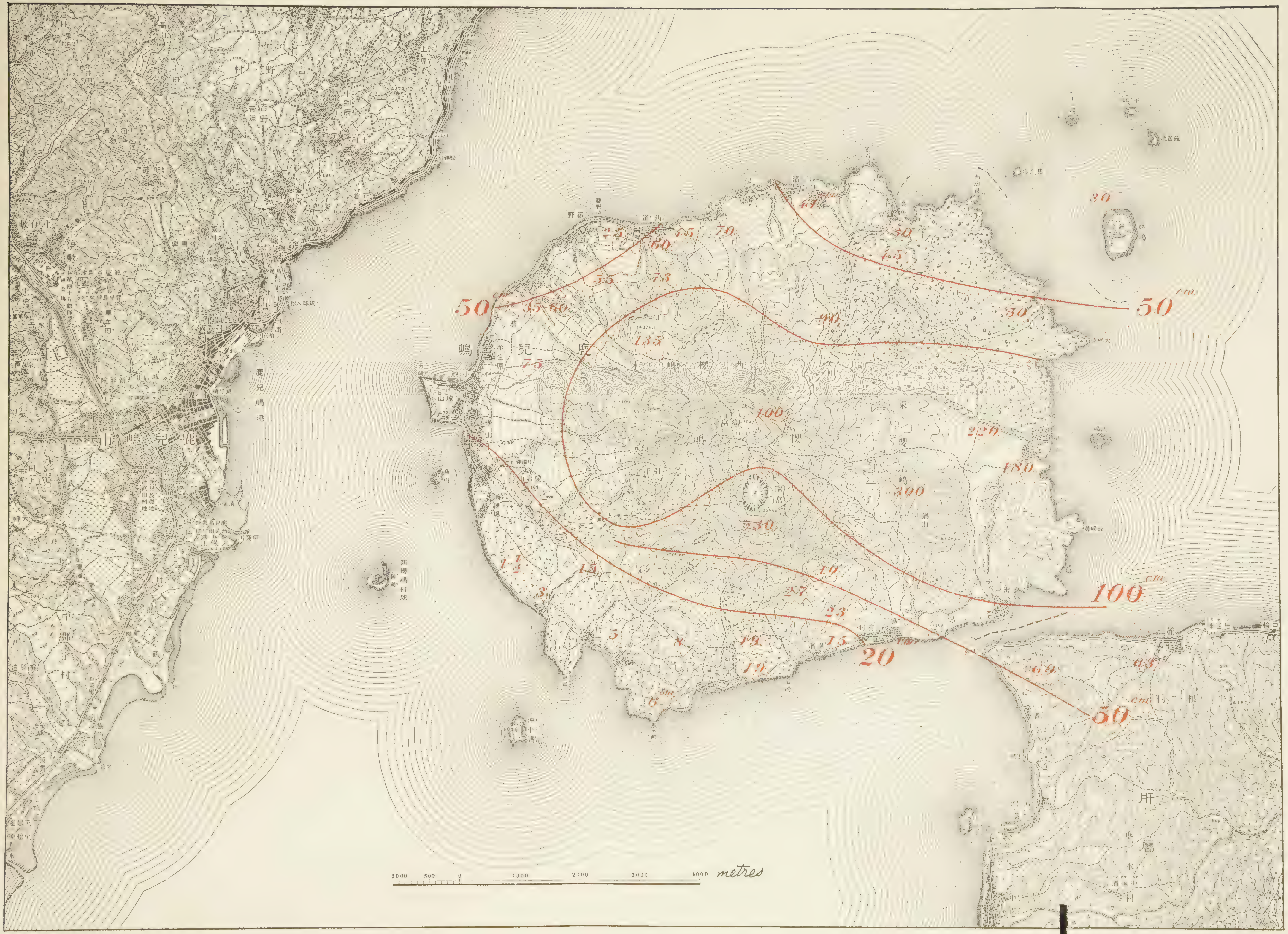
Fig. 31. Map showing the Accumulation of Pumice and Ash at different places in Sakura-jima.

(The figures give the thickness of the pumice and ash accumulation.)
The curves, drawn by interpolation, are the lines of
100, 50, and 20 cm accumulation respectively.

Pl. XXIV.



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As will be seen from the map (fig. 31), the precipitation of volcanic matter in the S.W. portion of the island, from Yunohama to the neighbourhood of Hakamagoshi, was very slight, namely, under 20 cm, and consisted of ashes only. This, together with a few limited localities in the N.W. coast of the island is the only district in the island, where vegetation was not seriously affected by the eruption. The northward extension of the curves of equal accumulation is due to the southerly wind which set in at Kagoshima from about the noon on the 13th (Jan. 1914).

36. Ash-precipitation in the vicinity of Sakura-jima. The map (fig. 33), which indicates the approximate distribution of amount of the ashes in the vicinity of Sakura-jima, namely, the S.E. portion of Kyushu, has been compiled from a great number of reports sent in by the village offices and tobacco plantation stations respectively to the

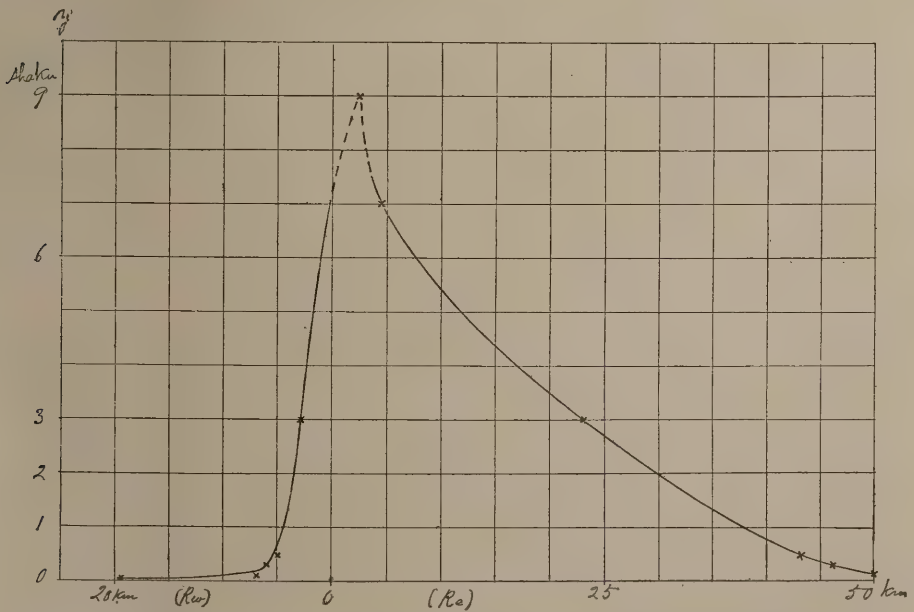


Fig. 32. Diagrammatic Representation of the Ash and Pumice Accumulation along an E.S.E.-W.N.W. line through the centre of Sakura-jima.
(1 *shaku* = 30.3 cm = 1 foot very nearly.)

Kagoshima meteorological observatory and Kagoshima Monopoly Bureau, supplemented with a few personal observations. The area of ash-precipitation of over 30 *sun* (=3 *shaku*=3 feet very nearly) was an ellipse stretching from the centre of Sakura-jima towards the E. slightly S. for a length of about 26 km, with the maximum width of 8½ km. The greatest length of the areas of the precipitation of over 5 *sun* (=6 inches), 3 *sun* (=3½ inches), and 1 *sun* (=0.1 foot) were respectively 47, 52, and 70 km. The land area of slight precipitation, or of ash-accumulation of 1 *sun* to about 1 mm, had a radial distance of 120 km in the N.E. direction, but one of only about 20 km toward the W.

The radial distances of the points of intersection of the different curves of equal precipitation amount with a line parallel to E10°S–W10°N, which is the direction of the major axis of the 30–*sun* area, are as follows :—

Westwards from Centre of Sakura-jima.		Eastwards from Centre of Sakura-jima.
——		(East coast of Sakura-j. = 5 km)
——		(Coast of Ushine, Ōsumi=11 „)
3 km	30–*sun* Line	23 km
5 „	5 „ „	43 „
6 „	3 „ „	46 „
7 „	1 „ „	50 „
22 „	1 mm line	(Stretches far out over the ocean.)

The profile of the cone, or accumulation, of pumice, sand, and ash, based on the above given figures and the observations at Krokami and on the Minami-dake and Kita-dake peaks, is given in Fig. 32, from which it will be seen that the eastern slope is, on an exaggerated scale, perfectly similar to the gradual logarithmic slope of Fuji-san type volcanoes, while the western slope is incomparably much steeper. From this fact, it can perhaps be

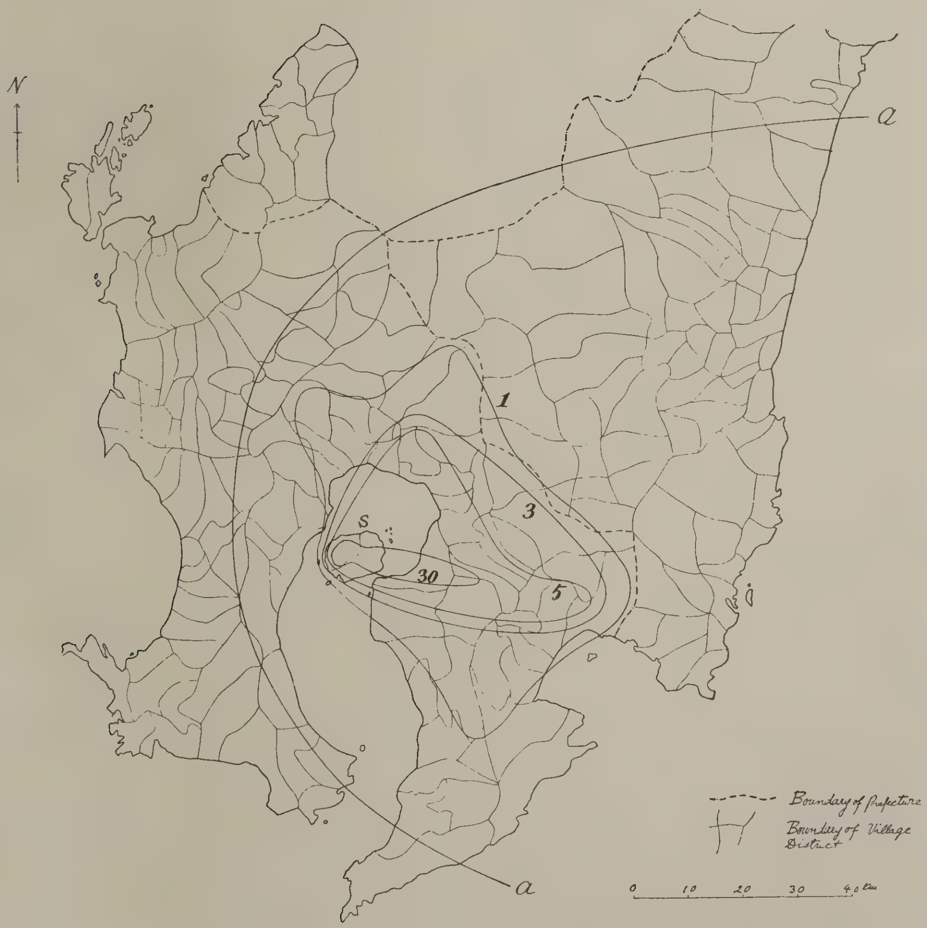
Pl. XXV.

Sakura-jima Eruption of 1914.

Fig. 33. Map showing the approximate Ash-distribution in the S. Portion of Kyushu.

The four inner curves are lines respectively of 30; 5; 3; and 1 *sun* accumulation. (1 *sun*=0.1 foot very nearly). The outermost curve (a) marks the boundary of the area of a slight ash-precipitation, about 0.1 *sun* or so.

S. . . . Sakura-jima.



infered that the form of a cinder and ash cone of large magnitude, resulting from a powerful outburst, must necessarily be unsymmetrical on account of the influence of the strong westerly current in the higher atmospheric region. The high regularity of the conical or logarithmic form of Fuji-san, Kaimon-dake, etc., must essentially depend on the lavas which flowed from the respective central craters. The outline of the volcano of Sakura-jima is also, on the whole, symmetrical with respect to the N.S. direction.

37. Ash-precipitation area. (See Table XXIV, A.) The ashes carried to furthest distances were those due to the strong outbursts during the first two days of the eruption, namely, Jan. 12th and 13th, 1914, the precipitation at different places having taken place on the 12th to 14th. As will be seen from fig. 34, the area in question included Main Island (Honshu), except its N.E. portion, its S.E. corner, and a narrow tract along the Japan Sea coast at the extreme W. end; the whole of Shikoku; and Kyushu, except very small portions at its S.W. and N.W. ends.

The ash-precipitation area was highly eccentric with respect to Sakura-jima, indicating a marked eastward extension, as is usual with great eruptions in Japan where the upper atmospheric current is westerly. So far as is shown in the map (fig. 34), the furthest transportation of the ashes was in the N.E. direction, to Ishinomaki and vicinity, the extreme radial distance* being 1231 km. It is, however, likely that a very small quantity of the ashes was transported also to some places situated outside the general precipitation area, in the N.E. directions. Thus, according to the report of the agricultural station of Hanatate (Senpoku county, province of Ugo), whose radial distance is 1245 km, the water obtained by liquifying the snow precipitated there during the 24 hours between 10 a.m., 15th, and 10 a.m., 16th, (Jan. 1914), was markedly turbid and ashy in colour, and gave a large quantity of deposits; the amount of the ashy material* contained in 1 litre of the water in question being 108.3 grams, against the average amount of 3.7 grams for the interval between Dec. 1st. 1913, and Jan. 4th, 1914. This difference represents probably the volcanic ash due to the eruption of Sakura-jima. Ash-precipitation was also reported from a few places near Niigata, in the province of Echigo.

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* Distances measured from the centre of Sakura-jima.

To the north from Sakura-jima, the ash-precipitation was not noticed at the W. coast of Hizen (in Kyushu) and in the islands of Iki (radial distance=267 km) and Tsushima (radial distance=319 km). A thin ashy cloud seems, however, to have spread some distance beyond these limits to the S.E. part of Chosen. Thus, at Fusan (radial distance=419 km), on the 13th (Jan. 1914), when the weather was fine and quiet, there appeared light mists in the early morning due probably to the dusts from Sakura-jima, which thickened at 9 a.m. to an unusual degree, such that the chimneys and other objects at a distance of some 800 m could only be dimly seen, and which were finally discipated on the commencement of rain at 9.50 a.m.

To the S.W. of Sakura-jima, there was on the 12th and 13th (Jan. 1914) no precipitation of the volcanic dusts in the S.W. part of Satsuma and the S. part of Ōsumi, the shortest distance of transportation of the ashes in the direction under consideration being only 15 km from the centre of the island. Here, again, the fine misty smokes spread some distance further beyond the limit of the area of the actual ash-precipitation. Thus, at Nakanoshima, situated about 200 km to the S.S.W. of Sakura-jima, the eastern sky was, from about 5 a.m. on the 13th (Jan. 1914), peculiarly orange in colour, while the air was misty, rendering it dark at noon as in the evening.

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* Solid material obtained by combusting the deposits.

38. Observations at meteorological stations. In Tables XXII and XXIII I summarize the observations at the different meteorological stations relating to the precipitation of the volcanic dusts of Sakura-jima.

Mists. It will be seen that in Kyushu, Shikoku, and in the western and Kinai districts of Main Island (Honshu), the ash-precipitation was preceded, at an interval of some 9 or more hours, by the development of a peculiar misty condition which rendered the atmosphere considerably opaque. These " mists " were undoubtedly caused by the floating of the extremely minute volcanic dusts given out during the earlier stage of the eruption, say, before 6 p.m. on the 12th (Jan. 1914), when the explosive force was not yet powerful to project to a sufficient elevation the coarser constituents of the ejecta to be precipitated as ash at great radial distances. Owing to the gradual appearance of the " mists," it would naturally be difficult to observe the exact time of their commencement. The earliest arrivals were reported from Kumamoto, Matsuyama, and Kobe, the times observed being 10 p.m. (12th), 6 a.m. (13th), and 7 a.m, (13th), corresponding to the radial distances (r) of 137, 317, and 544 km respectively. Assuming the moment of the beginning of the definite *radial* progress of the smokes first shot up from Sakura-jima to be 11 a.m. (12th, Jan.), we obtain the following rough values of the north-eastward translation velocity of the " misty ash " :—

To Kumamoto ($r=137$ km) .... Velocity $=12.5$ km/hour $=3.5$ m/s.
,, Matsuyama ($r=317$,,) .... ,, $=16.7$,, $=4.6$
,, Kobe ($r=544$,,) .... ,, $=27.2$,, $=7.6$

Ashes. The accumulation of the ashes was slight except in the S.E. portion of Kyushu. In the N.E. direction from the volcano the precipitation was reduced to 1 mm already at the radial distance of some 150 to 200 km, the decrease in the northern direction being still more rapid. Owing to the smallness of the amount of ash at distant places, the time of commencement of the precipitation, happening in night in many cases, was observed but approximately at the different meteorological stations, probably with the exception of that of Miyazaki, where the accumulation was not insignificant. According to Table XXII, the earliest time of ash-precipitation, reported from the last mentioned place, was 1¾ a.m., 13th. Then come Ōita, Kōchi, and Matsuyama, respectively at 8½, 6, and 10 a.m., 13th. At Ōsaka, Kyoto, Iida, and Tsukuba, the precipitation began during the night of the 13th, while at other places in the central and northern parts of Main Island, it was noticed first generally at the early hours of the 14th. Assuming the ashes precipitated at places of great radial distance to be due to the smokes thrown out from Sakura-jima with reinforced violence after 6 p.m., 12th, we get the values of their transit velocity indicated in the 4th column of Table XXI, in which (I) includes the places lying to the N.E., and (II) those lying to the N. or N.N.E., from Sakura-jima.

Again, referring the times of commencement of precipitation of ash at the different distant places to that at Miyazaki, and calculating by the difference method, we get the values of the transit velocity of the volcanic dusts indicated in the last column of Table XXI.

The ash-precipitation became thicker at Miyazaki from 1 p.m., at Kōchi and Tokushima from 8 to 8½ p.m., on the 13th, and at Ōsaka, Yagi, and Wakayama from 2 to 10 a.m., on the 14th; namely, 11¼, 9½, 14, 2, 8, and 11 hours after the time of the commencement of the ash-precipitation respectively, giving, with the exception of Ōsaka, an average value of about $10\frac{3}{4}$ hours. The increase in the precipitation, possibly influenced by the change in the distribution of the barometric pressure over Japan on the 13th and 14th (Jan.), may also denote a stage in the eruption when the ashes began to be thrown out more copiously.

TABLE XXI. APPROXIMATE TRANSIT VELOCITIES OF THE ASHES.

Group.	Place.	Radial Distance.	Average Transit Velocity of Ashes.	
			Direct Calculation.	Calculation by "Difference Method." (Referred to the time of Commencement at Miyazaki.)
I	Miyazaki.	83km.	10.7km/hour.	— km/hour.
	Ōita.	206	14.2	18.2
	Kōchi.	347	29.0*	62.1*
	Matsuyama.	317	19.8	28.4
	Besshi.	355	19.2	25.3
	Ōsaka.	560	18.7	21.4
	Yagi.	579	18.1	20.5
	Kyoto.	606	23.3	28.7
	Wakayama.	512	24.4	32.4
	Tsu.	647	19.5	21.1
	Hamamatsu.	743	21.9	25.2
	Iida.	796	28.4	35.2
	Mito.	1048	27.6	31.9
	Ishinomaki.	1231	29.3	33.5
II	Kumamoto.	137	7.4	5.0
	Shimonoseki.	266	12.7	13.8
	Sakai.	501	23.8	31.6
	Hiroshima.	353	18.6	24.1

* The high values of the velocity for Kōchi is only apparent, the time of commencement of the ash-precipitation at Kōchi (6 a.m., 13th) corresponding probably to the arrival of the "Mists" at the other places.

39. Observation in Ogasawara-jima (Bonin Islands).* According to the report of Mr. Y. Yoshida, director of the meteorological observatory of Chichi-jima, in the Bonin islands group, the circumstances of the ash-precipitation at Futami Harbour were as follows:— On the 12th (Jan. 1914), the sky was cloudy, but the air was dry under the high barometric pressure of 766 mm, with slight N.E. wind. On the morning of the 13th, at about 5. 30 a.m., the arrival of the dense cloudy matter, which was like the sudden visitation of a squall, rendered the air dark, and was at first mistook for development of thick mists by the people, who were, however, soon undeceived, as the fine gray ashes began to fall down. The precipitation was most marked for about 1½ hours, from 6¼ to 7¾ a.m., and thinly covered the ground and leaves of plants, while the sun looked like a dull white disc amid the dusky sky. The coast of Ōgi-ura on the opposite side of Futami Bay at a distance of 2 miles could but be dimly discerned. From about 9 a.m. the sun began to recover slightly its brightness, but it was only at about 5 p.m. that the weather almost regained its usual aspect. There still remained, however, some mistiness in the air, and in the night the moon and stars shone lazily. A slight fall of rain at a little past 9 p.m. made no change, and the same condition of a milky haziness of the atmosphere continued throughout the 14th and 15th, when high cirrus clouds came floating from the west. On the 16th (Jan. 1914), there developed from the early morning a misty condition which was thicker than on the 13th, fine ashy particles being suspended in the air. After 1 p.m., the sun shone out, but the weather did not regain its ordinary condition, it becoming again dark before the evening. During the night the apparent mist became thin. At Haha-jima, in the same Bonin group, the precipitation of ashes is said to have been most marked between 8 and 9 a.m. on the 13th.*

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* For the positions of Ogasawara-jima (Bonins) and Kita, Naka, and Minami Iwo-jima (Volcano Islands), see fig. 1 (Pl. VIII).

If we assume the ashes precipitated at 5. 30 a.m. on the 13th in Chichi-jima, at a radial distance of 1222 km to the S. 68°E. of Sakura-jima, to be due to the transportation of the smoke masses powerfully projected at the commencement of the eruption of the latter, which reached the height of over 3000 m at about $11\frac{1}{2}$ a.m., the average velocity of the S.E. progress of the fine ashes in question comes out to be

$$\frac{1222 \text{ km.}}{18 \text{ hours}} = 67.9 \text{ km/hour} = 18.8 \text{ m/sec.}$$

At Naka-Iwo-jima (Volcano Islands group), lying at a radial distance of 1290 km to the S.57°E. of Sakura-jima, there was some ash-precipitation on the 15th or 16th of Jan., 1914, turning tree leaves slightly gray in colour.

40. Remarks on transportation of ashes. Comparing together what was said in §§ 36, 37, and 38, it seems that the ashes of the Sakura-jima eruption were carried eastwards, that is to say, toward the directions of N.E. to S.E., the extreme radial distances being over 1200–1300 km. As, however, there was no precipitation of the volcanic dust at Hachijō-jima, situated at the distance of 877 km to the N.76°E. of Sakura-jima, the ashes transported N.E.'wards over Shikoku and Main Island and those transported S.E.'wards to the Bonins and Volcano Islands might have belonged to the different stages of the eruption. The following seems, however, to be a more probable explanation of the ash-distribution in question :—As the height attained by the explosive smokes of Sakura-jima was considerable, while the craterlets themselves were at low levels of under 500 m, it is to be expected that the transportation of the ashes to places of different distances depended both on the high and the surface air currents. Thus the ash-precipitation at Ogasawara-jima (Bonins) and Volcano Islands was probably due to the swift upper winds, while that in Main Island, Shikoku, and Kyushu, was effected by the S.W.'ly surface winds, connected with the appearance in the night of the 13th and in the early morning of the 14th, Jan. 1915, of a deep low pressure centre (744 mm) on Japan Sea.

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* It is true that the eruption of Sakura-jima was closely followed by the submarine outburst from a point situated 3 miles to the east of Minami Iwo-jima, in the Volcano Islands group, whose smokes were first observed on the 23rd of January (1914), at 4. 50 p.m., from Naka Iwo-jima, situated at a distance of only 60 miles from the scene of disturbance. The ashes which fell in the Ogasawara-jima on the 13th seem to be due to the eruption of Sakura-jima on the 12th.

For the N.E.'ly ash-transportation, the different places in Kyushu, Shikoku, and Main Island, considered in § 38, may be grouped according to the radial distance ($=r$), as in the following table, in which a mean value is indicated by gothic numerals, a figure enclosed in brackets being the number of cases from which it has been deduced.

Method of Calculation.	$r<300$ km	$300<r<600$ km*	$600<r<1231$ km
	km/h km/h	km/h	km/h
Direct Method.	7.4—14.2	**20.4**(7)	**25.0**(6)
Difference Method : referred to Miyazaki.	5.0—13.8	**26.3**(7)	**29.3**
" Misty Ashes."	12.5	16.7—27.2	

The mean ash-transportation velocity calculated by the " difference method " is $v_1=26.3$ km/h for the radial distances between 300 and 600 km, and increased to $v_2=29.3$ km/h for those between 600 and 1231 km ; the corresponding values calculated by the " direct method " being a little smaller, namely, 20.4 and 25.0 km/h respectively. The velocity for the radial distances less than 300 km was much smaller, the maximum value being about 14 km/h. The transportation velocity of the "misty ashes" was probably not different from that of the ordinary volcanic dusts.

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* Kōchi omitted.

The "difference method" values of the velocity v_1 and v_2 are equivalent respectively to 7.3 and 8.1 m/sec., with the mean value of 7.7 m/sec. Now, on account of the cyclonic weather from the evening of the 13th to the morning of the 15th (Jan. 1914), there prevailed S.W.'ly winds over the central and western Japan, whose mean daily velocity at the different places within the ash-precipitation area varied on the 13th from 0.82 to 3.5 m/sec., and on the 14th from 3.7 to 13.5 m/sec., with the average values of 2.1 and 7.7 m/s. for these two days respectively. The latter average is accidentally identical with the general mean velocity of the ash-transportation above mentioned, which might have depended mainly on the surface winds or those at low altitude.

The high velocity of 67.9 km/hour or 18.8 m/sec., with which the ashes of the Sakura-jima eruption reached Ogasawara-jima (Bonin Islands) is not much different from the values obtained in the case of the Asama-yama eruptions,* for the radial distances under 145 km, as follows:—

Asama Eruption of Dec. 7th, 1909	22 m/sec.
,, ,, ,, Jan. 3rd, 1911	17
,, ,, ,, ,, 6th, ,,	35
Mean	24 m/s=86.4 km/h

41. Ash-precipitation on and after Jan. 15th, 1914. In Table XXIV, B is given a list of places where ash-precipitation took place, which was due to the after-outbursts of Sakura-jima.

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* See the Bulletin, Vol. VI, p. 69.

Only on the two days, Jan. 18th and 20th, (1914), ash-precipitation was reported from places outside of Kyushu, namely, from Kyoto and Ōsaka (radial distance=606 and 560 km) and from Katahara and Toyohama, in the provinces of Owari and Mikawa (radial distance=700 km), respectively. At Kumamoto (radial distance=137 km) and Mitai in the N.W. corner of Hyuga (radial distance=140 km), however, the ash-precipitation took place on several occasions; that at the former place dating as late as the 1st and 19th of April, 1914. It thus seems that the after-outbursts were unable to send ashes, except on only a few cases, to distances much above 150 km from the volcano, in the N. or N.E. direction. Again, on the 15th, 16th, 17th, and 19th of Jan. 1914, the ash-precipitation was reported from about one to two dozen places, within area over 200 km in extension; while on the subsequent dates it was limited to only a few places or a single district. This indicates, in conjunction with the falling of ashes in Mikawa and Owari above noticed, that the eruptive energy was reduced in a marked and almost abrupt manner after the 19th and 20th of Jan. (1914): a conclusion which is in perfect accordance with the results of the tromometer observations.

In fig. 29 is shown the area of ash-precipitation on Jan. 17th, 1914, which extended in the N.S. direction for a distance of nearly 300 km, and included the whole of Satsuma, the three islands of Koshiki-jima, Iwo-jima, and Yaku-shima, the S. extremity of Ōsumi, the S.W. portion of Higo, the Shimabara peninsula of Hizen, and the N.W. corner of Hyuga. The ash-precipitation areas on Jan. 15th, 16th, and 19th were somewhat smaller in extension than, but very much similar to, that on the 17th. Now, as will be seen from Chapter III, the barometric distribution over Japan on the 17th of January was nearly identical to that on the 12th to 13th of the same month; there being in each case an area of high barometric pressure of 770 to 772 mm covering the S.W. part of Japan. Yet the ashes were carried on the occasion of the first outbursts principally eastwards, while on the 15th to 17th, and on the 19th, the precipitation took place principally toward the S.W. and the N., but not toward the E. It is probable that in very strong explosions of Jan. 12th–13th, when the smoke columns were projected vertically upwards to a considerable elevation, the ashes were carried toward the east by the swift westerly current in the higher atmospheric region. In cases of the small outbursts, however, the precipitation of ash depended entirely on the surface winds or on those at a slight elevation, which, on the 17th of January and other dates under consideration, were governed by the existence of a high barometric area in the western and central Japan.

TABLE XXII. ASH-PRECIPITATION AT DIFFERENT PLACES.

[Observations at Meteorological Observatories.]

Place.	Time of Ash-precipitation.	Amount of Ash-precipitation.
Kumamoto.	Misty from 10 p.m., 12th. Precipitation of ash from 0½ to 11 p.m., 13th.	The ground had the appearance of being covered with white sand.
Miyazaki.	Ash-precipitation from 1¾ a.m., 13th, became thick from 1 and continued till 7½ p.m., the same day.	Thickness = 1.1 mm (measured on the 13th).
Fukuoka.	8 a.m. till night, 13th.	Tree leaves became slightly white.
Ōita.	Misty from morning; ash-precipitn, which began at 8.30 a.m.; becoming strongest at 6 p.m., and ending at 11.45 p.m., 13th.	Ground surface was white as in a frost.
Saga.	Apparently enveloped in thick mist in the forenoon, with ash-preciptn. on the afternoon, 13th.	
Nagasaki.	Apparently enveloped in thick mist from early morning, 13th.	Tree leaves became white.
Kōchi.	Ash-precipitation from 6 a.m., being thickest at 8 p.m., 13th.	Waters of ponds became turbid.
Matsuyama.	Misty from 6 a.m., precipitation of ash becoming visible from 10 a.m., 13th.	Ashes adhered to tree leaves.

TABLE XXII. (*Cont.*)

Place.	Time of Ash-precipitation.	Amount of Ash-precipitation.
Tadotsu.	Misty from 9 a.m.; ashes fell in the evening, 13th.	Black boards were thinly covered with ashes.
Besshi.	Misty from 10 a.m.; ashes fell at 0.30 p.m., 13th.	It was like a very thick mist.
Tokushima.	Ash-precipitation from 8½ to 11 p.m., 13th.	It was like a severe frost.
Shimonoseki.	Misty from morning, intensified at 3 p.m., 13th. Actual precipitation of ash was not observed.	The ground was thinly covered with ash.
Sakai.	Misty from 1 p.m.; ashes fell at 3–4 p.m., 13th.	Verandahs were thinly covered with ashes. During night, street electric lights were dim.
Hamada.	Misty from morning, 13th.	No ash-precipitation.
Hiroshima.	Ash-precipitation from 1 p.m., 13th.	House roofs became white.
Kōbe.	Misty from 7 a.m., 13th.	House roofs were very slightly covered with ash.
Ōsaka.	Ash-precipitation from midnight, 13th, thickest from 2–3 till 7 a.m., 14th.	The ground looked as if covered by frost. 5 grams of ash were collected on a sheet of paper, 4 ft square.
Yagi (Nara).	Misty from afternoon, 13th, with ash-precipitation from 2–4 a.m., and thickest at 10 a.m., 14th.	Traces of ash were found on earth-thermometers.
Hikone.	——	Slight ash-precipitation, not directly observed.
Kyoto.	Ash-precipitation at 8–9 p.m., 13th.	Slight.
Tsu.	Ash-precipitation between 4½ and 6 a.m., 14th.	Very slight traces left on black boards.
Wakayama.	Misty from morning, thickened at 3 p.m., 13th, with ash-precipitation at 1–2 a.m., 14th.	Floors were slightly covered with ashes.
Ushio-misaki.	——	Slight.
Fukui.	——	Only a trace.
Hamamatsu.	Ash-precipitation at 4 a.m., 14th.	
Numazu.	„ before 6 a.m., 14th.	Green tree leaves became slightly white.
Matsumoto.	„ at the dawn, 14th.	
Iida.	„ before 10 p.m., 13th.	Traces of ash found on black boards.
Yokohama.	Ash-precipitation from early morning, 14th.	
Kumagai.	Ash-precipitation from early morning, 14th.	

Fig. 3

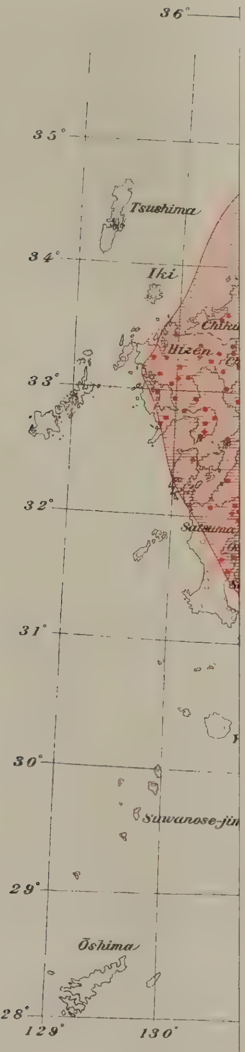

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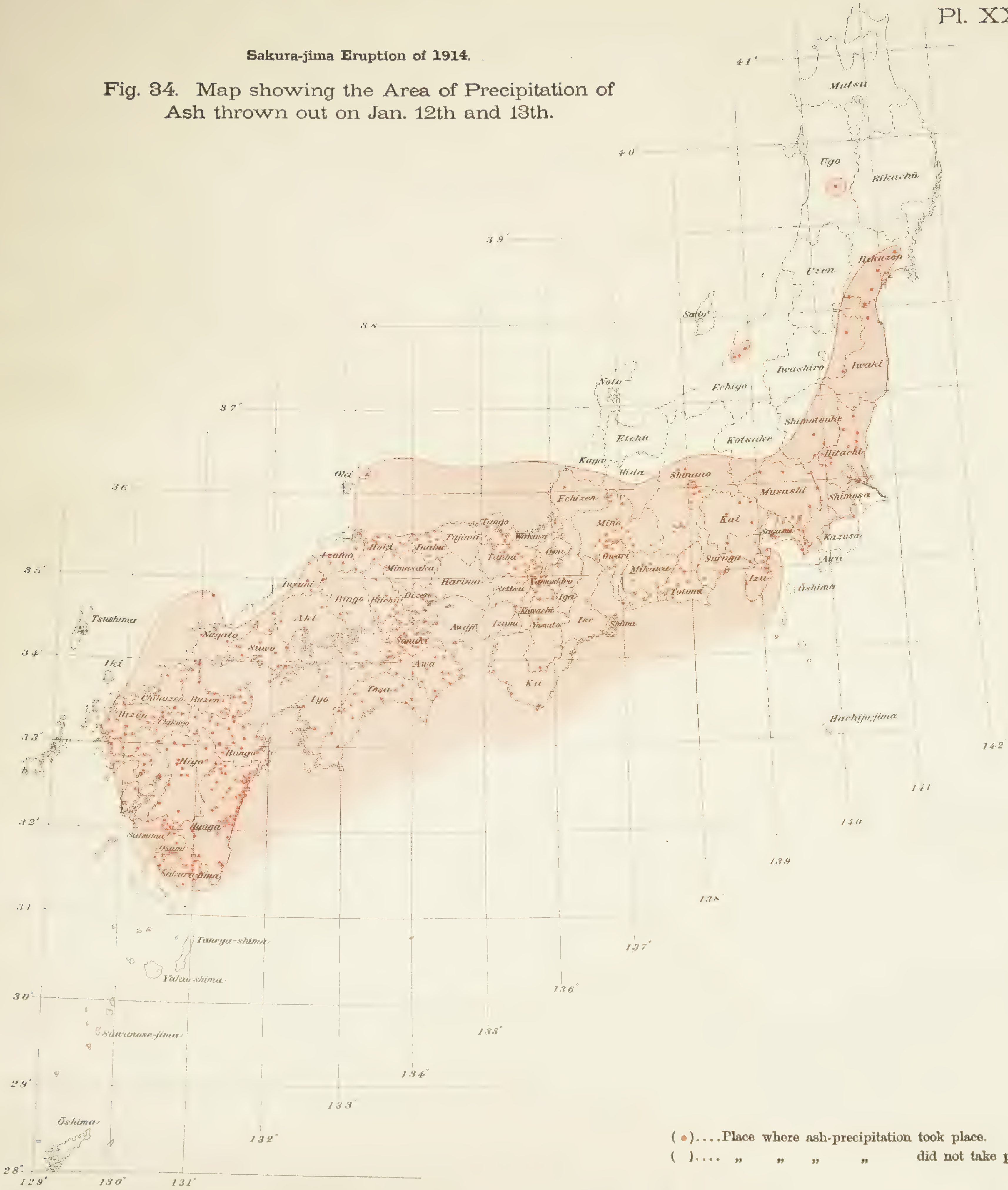
Fig. 34. Map showing the Area of Precipitation of Ash thrown out on Jan. 12th and 13th.



(●)....Place where ash-precipitation took place.

(　)....　„　„　„　„　did not take place.

TABLE XXII. (*Cont.*)

Place.	Time of Ash-precipitation.	Amount of Ash-precipitation.
Nagatsuro.	Ash-precipitation from early morning, 14th.	
Tsukuba.	Ash-precipitation between evening, 13th, and morning, 14th.	
Utsunomiya.	Ash-precipitation at 11½ a.m.?, 14th.	
Mito.	Ash-precipitation at 8–8½ a.m. 14th.	
Fukushima.	,, ,, 3 p.m.?, 14th.	
Hanadate.	,, from 10 a.m., 15th. till 10 a.m., 16th.	
Ishinomaki.	Ash-precipitation at 0–2 p.m., 14th.	Trace of ash like dust was found on floors.

TABLE XXIII. LIST OF RADIAL DISTANCE OF, AND APPROXIMATE TIME OF ASH-PRECIPITATION AT, DIFFERENT METEOROLOGICAL OBSERVATORIES.

(Jan. 1914.)

Place.	Radial Distance.	Air became misty at	Ash-precipitation	
			began at	became thicker
		[Kyushu.]		
Kumamoto.	km 137	12th, 10 p.m.	13th, 0½ p.m.	—
Miyazaki.	83	—	,, 1¾ a.m.	13th, 1 p.m.
Ōita.	206	13th, morning.	,, 8½ ,,	,, 6 ,,
		[Shikoku.]		
Kōchi.	347	—	13th, 6 a.m.	13th, 8 p.m.
Matsuyama.	317	13th, 6 a.m.	,, 10 ,,	—
Besshi.	355	,, 10 ,,	,, 0½ p.m.	—
Tadotsu.	417	,, 9 ,,	—	—
Tokushima.	457	—	—	13th, 8½ p.m.
		[Honshu: W. Part.]		
Shimonoseki.	266	13th, morning.	13th, 3 p.m.*	—

TABLE XXIII. (*Cont.*)

Place.	Radial Distance.	Air became misty at	Ash-precipitation.	
			began at	became thicker
Sakai.	km 501	13th, 1 p.m.	13th, 3–4 p.m.	——
Hiroshima.	353	——	„ 1 „	——
[Honshu : Kinai and Vicinity.]				
Kobe.	544	13th, 7 a.m.	——	——
Ōsaka.	560	——	13th, 12 p.m.	14th, 2–3 a.m.
Yagi.	579	13th, afternoon.	14th, 2–4 a.m.	14th, 10 a.m.
Kyoto.	606	——	13th, 8–9 p.m.	——
Wakayama.	512	13th, morning.	13th, 3 p.m.*	14th, 2 a.m.
Tsu.	647	——	14th, 4½ a.m.	——
[Honshu : Central and Northern Parts.]				
Hamamatsu.	743	——	14th, 4 a.m.	——
Iida.	796	——	13th, before 10 p.m.	——
Tsukuba.	1004	——	13th, during the night.	——
Mito.	1048	——	14th, 8 a.m.	——
Ishinomaki.	1231	——	„ 0–2 p.m.	——

TABLE XXIV, A. LIST OF PLACES WHERE ASH-PRECIPITATION TOOK PLACE ON 12TH, 13TH, AND 14TH, JAN. 1914.

Places where ash-precipitation took place on the 12th :—

Kagoshima Pref. (Satsuma and Ōsumi). 鹿兒島, Kagoshima. 東南方, Higashi-Minakata. 岩川, Iwakawa. 恒吉, Tsuneyoshi. 市成, Ichinari. 財部, Takarabe. 末吉, Sueyoshi. 松山, Matsuyama. 志布志, Shibushi. 月野, Tsukino. 野方, Nogata. 大崎, Osaki. 加治木, Kajiki. 西國分, Nishi-Kokbu. 牧園, Makizono. 東國分, Higashi-Kokbu. 福山, Fukuyama. 栗野, Kurino. 重富, Shigetomi. 山野, Yamano. 羽月, Hazuki. 西太頁, Nishi-Taira.

Miyazaki Pref. (Hyuga). 福島, (南那珂郡), Fukushima. 油津, Aburatsu. 都城, Miyakonojō. 加久藤, Kakto. 飫肥, Obi.

Kumamoto Pref. (Higo). 高森, Takamori. 宮地, Miyaji.

Fukuoka Pref. (Chikugo). 柳川, Yanagawa.

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* Time when the misty condition of air increased, being here assumed to correspond to the commencement of ash-precipitation.

Nagasaki Pref. (Hizen). 神代, Kōjiro. 南有馬, Minami-Arima.

Saga Pref. (Hizen). 伊萬里, Imari. 古湯, Furuyu.

Places where ash-precipitation took place on the 13th:—

Kagoshima Pref. (Satsuma and Ōsumi). 鹿兒島, Kagoshima. 上出水, Kami-Izumi. 郡山, Kōriyama. 岩川, Iwakawa. 恒吉, Tsuneyoshi. 市成, Ichinari. 財部, Takarabe. 末吉, Suyeyoshi. 松山, Matsuyama. 志布志, Shibushi. 月野, Tsukino. 野方, Nogata. 大崎, Ōsaki. 加治木, Kajiki. 西國分, Nishi-Kokbu. 溝邊, Mizobe. 牧園, Makizono. 東襲山, Higashi-Soyama. 東國分, Higashi-Kokbu. 福山, Fukuyama. 栗野, Kurino. 淸水, Shimizu. 横川, Yokogawa. 帖佐, Chōsa. 國分, Kokbu. 西襲山, Nishi-Soyama. 蒲生, Gamo. 吉松, Yoshimatsu. 山野, Yamano. 羽月, Hazuki. 西太良, Nishi-Daira. 大口, Ōguchi. 惠太良, Yetara. 菱刈, Hishikari.

Miyazaki Pref. (Hyuga). 宮崎, Miyazaki. 高原 (西諸縣郡), Takahara. 延岡, Nobeoka. 南郷 (東臼杵郡), Minamigo. 椎葉 (西臼杵郡), Shiiba. 高鍋, Takanabe. 都城 Miyakonojō. 小林, Kobayashi. 飫肥, Obi.

Kumamoto Pref. (Higo). 熊本, Kumamoto. 人吉, Hitoyoshi. 佐敷 (葦北郡), Sashiki. 本渡 (天草郡), Hondo. 八代, Yatsushiro. 三角, Misumi. 砥用 (下益城郡), Tomochi. 松橋 (下益城郡), Matsubashi. 御船 (上益城郡), Mifune. 春日 (飽託郡), Kasuga. 高森 (阿蘇郡), Takamori. 宮地 (阿蘇郡), Miyaji. 高瀨, Takase. 隈府, Waifu. 山鹿, Yamaga.

Fukuoka Pref. (Chikzen, Chikugo, and Buzen). 福岡, Fukuoka. 柳川, Yanagawa. 大牟田, Ōmuta. 福島, Fukushima. 久留米, Kurume. 北野, Kitano. 吉井, Yoshii. 甘木, Amaki. 西新町, Nishi-Shinmachi. 箱崎, Hakozaki. 東郷, Togo. 折尾, Orio. 直方, Nōgata. 行橋, Yukuhashi. 門司, Mozi.

Nagasaki Pref. (Hizen). 南有馬, Minami-Arima. 神代, Kōjiro. 溫泉, Uuzen. 口加, Kōka.

Saga Pref. (Hizen). 佐賀, Saga. 鳥栖 (三養基郡), Tosu. 藤津, Fujitsu. 神崎郡 (農學校), Kanzaki. 小城, Ogi. 武雄, Tokeo.

Ash-precipitation took place on the 13th also at different places throughout the prefectures of Ōita (Bungo), Tokushima (Awa, in Shikoku), Kōchi (Tosa), Kagawa (Sanuki), Yamaguchi (Nagato and Suwō), Hiroshima (Aki and Bingo), Okayama (Bizen, Bitchu, and Mimasaka), Shimane (Izumo, Iwami, and Oki), Tottori (Inaba and Hōki), Ōsaka (Settsu, Izumi, and Kawachi), Nara (Yamato), and Wakayama (Kii); and on Mount Tsukuba, and in parts of the prefectures of Kyoto (Yamashiro, Tanba, and Tango) and Aichi (Owari and Mikawa).

Places where ash-precipitation took place on the 14th:—

Kagoshima Pref. (Satsuma and Ōsumi). 硫黃島, 甑島, 下屋久, Islands of Iwo-jima, Koshiki-jima, and Yaku-shima. 佐多, Sata. 東南方, (川邊郡), Higashi-Minakata. 中伊集院, Naka-Ijuin. 郡山, Kōriyama. 花岡, Hanaoka. 牧園, Makizono. 福山, Fukuyama. 山田, Yamada. 蒲生, Gamo.

Miyazaki Pref. (Hyuga). 都城, Miyakonojō. 飫肥, Obi. 高千穗 (西臼杵), Takachiho. 延岡, Nobeoka.

Kumamoto Pref. (Higo). 人吉, Hitoyoshi. 砥用 (下益城郡), Tomochi. 御船 (上益城郡), Mifune. 春日 (飽託郡), Kasuga.

Fukuoka Pref. (Chikzen, Chikugo, and Buzen). 福島, Fukushima. 箱崎, Hakozaki. 行橋, Yukuhashi. 小倉, Kokura. 門司, Moji.

Yamaguchi Pref. (Suwō and Nagato). 防府, Bofu. 德山, Tokuyama. 德佐 (阿武郡), Tokusa. 田耕, Tasuki.

Okayama Pref. (Mimasaku). 奥津 (苫田郡), Okutsu.

Saga Pref. (Hizen). 嬉野, Ureshino.

Tokushima Pref. (Awa). 石井町 (名西郡), Ishii-machi. 椿 (那賀郡), Tsubaki. 富岡 (那賀郡), Tomioka. 鳴門 (板野郡), Naruto.

Kōchi Pref. (Tosa). 中村 (幡多郡), Nakamura. *Ehime Pref.* (Iyo). 新居濱, Niihama.

Ibaraki *Pref.* (Hitachi). 水戸, Mito. 筑波, Tsukuba. *Miyagi Pref.* (Rikzen). 石卷, Ishinomaki.

On the 14th, the ash-preciptation took place also at Kōbe, Ōsaka, Tsu, and Tokyo; and at several places in the prefectures of Shimane (Iwami, Izumo), Wakayama (Kii), Nara (Yamato), Kyoto (Yamashiro, Tanba, Tango), Aichi (Owari, Mikawa), Gifu (Mino, Hida), Fukui (Echizen, Wakasa), Shizuoka (Totomi, Suruga, Izu), Kanagawa (Musashi, Sagami), etc.

TABLE XXIV, B. LIST OF PLACES WHERE ASH-PRECIPITATION TOOK PLACE ON AND AFTER THE 15TH OF JAN. 1914.

All the places, unless otherwise marked, belong to Kagoshima prefecture. Those marked 1, 2, 3, 4, 5, and 6, belong respectively to the provinces of Hyuga, Buzen, Higo, Hizen, Owari, and Mikawa. On Jan. 18th, 1914, there was a slight ash-precipitation in Kyoto and Ōsaka.

Jan. 15th.	硫黄島 Iwo-jima.	郡 山 Koriyama.	飫 肥 Obi.
	甑 島 Koshiki-jima.	花 岡 Hanaoka.	三田井 Mitai.
	下屋久 Yaku-shima.	内之浦 Uchinoura.	行 橋 Ikuhashi.
	隈之城 Kumanoki.	蒲 生 Gamo.	
Jan. 16th.	硫黄島 Iwo-jima.	今和泉 Imaizumi.	小根占 Konejime.
	下屋久 Yaku-shima.	指 宿 Ibsuki.	大根占 Onejime.
	東市來 Higashi-Ichiku.	山 川 Yamagawa.	田 代 Tashiro.
	吉 永 Yoshinaga.	頴 娃 Yei.	三田井 Mitai. (1)
	喜 入 Kiire.	鹿 屋 Kanoya.	
Jan. 17th.	鹿兒島 Kagoshima.	中伊集院 Naka-Ijuin	今和泉 Imaizumi.
	硫黄島 Iwo-jima.	上伊集院 Kami-Ijuin.	指 宿 Ibusuki.
	甑 島 Koshiki-jima.	郡 山 Koriyama.	山 川 Yamagawa.
	下屋久 Yaku-shima.	日 置 Hioki.	頴 娃 Yei.
	佐 多 Sata.	吉 利 Yoshitoshi.	三田井 Mitai. (1)
	上出水 Kami-izumi.	田布施 Tabuse.	佐 敷 Sashiki. (3)
	隈之城 Kumanoki.	阿 多 Ada.	本 渡 Hondo. (3)

TABLE XXIV, B. (*Cont.*)

Jan. 17th.	西市來 Nishi-Ichiku. 下伊集院 Shimo-Ijuin.	加世田 Kaseda. 喜入 Kiire.	溫泉 Unzen. (4)
Jan. 18th.	硫黃島 Iwo-jima. 甑島 Koshiki-jima. 三田井 Mitai. (1)	下屋久 Yaku-shima. 喜入 Kiire.	大阪 Ōsaka. 京都 Kyoto.
Jan. 19th.	鹿兒嶋 Kagoshima. 中之島 Nakano-shima. 硫黃島 Iwo-jima. 下屋久 Yaku-shima. 佐多 Sata. 上出水 Kami-Izumi.	中伊集院 Naka-Ijuin. 上伊集院 Kami-Ijuin. 日置 Hioki. 阿多 Ada. 加世田 Kaseda. 喜入 Kiire.	指宿 Ibsuki. 山川 Yamagawa. 宮崎 Miyazaki. (1) 三田井 Mitai. (1) 熊本 Kumamoto. (3) 佐敷 Sashiki. (3)
Jan. 20th.	高鍋 Takanabe. (1)	形原 Katahara. (6)	豐濱 Toyohama. (5)
Jan. 21st.	高鍋 Takanabe. (1)		
Jan. 22nd.	鹿兒島 Kagoshima. 郡山 Koriyama. 阿多 Ada.	加世田 Kaseda. 喜入 Kiire.	指宿 Ibsuki. 山川 Yamagawa.
Jan. 23rd.	鹿兒嶋 Kagoshima.		
Jan. 24th.	鹿兒嶋 Kagoshima.	隈之城 Kumanoki.	佐敷 Sashiki. (3)
Jan. 26th. Feb. 2nd. Feb. 5th.	今和泉 Imaizumi. 今和泉 Imaizumi. 加世田 Kaseda.	Jan. 29th. Feb. 4th.	熊本 Kumamoto. (3) 阿多 Ada.
Feb. 7th.	上出水 Kami-Izumi. 郡山 Koriyama. 日置 Hioki.	阿多 Ada. 喜入 Kiire.	熊本 Kumamoto. (3) 佐敷 Sashiki. (3)
Feb. 15th.	中伊集院 Naka-Ijuin.	佐多 Sata.	
Feb. 17th.	熊本 Kumamoto. (3)	佐敷 Sashiki. (3)	
Feb. 19th. March 6th. March 17th. March 27th. April 1st. April 17th.	上伊集院 Kami-Ijuin. 熊本 Kumamoto. (3) 佐多 Sata. 佐多 Sata. 熊本 Kumamoto. (3) 佐多 Sata.	March 5th. March 15th. March 20th. March 31st. April 6th. April 19th.	佐敷 Sashiki. (3) 佐多 Sata. 熊本 Kumamoto. (3) 佐多 Sata. 佐多 Sata. 熊本 Kumamoto. (3)

CHAPTER VI. ABNORMAL CHANGES IN HEIGHT OF WATER OF KAGOSHIMA BAY DUE TO THE SAKURA-JIMA ERUPTION OF 1914.

42. Tide-gauge observations at Kagoshima. The first systematic determinations of the height of sea-surface in the harbour of Kagoshima were made by the public-works department of Kagoshima Prefecture for 2⅓ years from Jan. 1903 to April 1905, and also for 1 month from May 12th to June 12th, 1909, the water level having been read off at 10 minutes intervals throughout the day and night by means of a graduated tide-gauge rod erected at the harbour office quay, whose zero corresponded to 14,61 *shaku* below the Military Survey Bench-Mark, No. 2469, set up on the adjacent strand street of Ogawa-machi (小川町). The highest water level during the above mentioned time intervals was 11.3 *shaku* and was attained on Sept. 11th, 1904. In Table XXX is given the monthly height of sea-level for the interval between Jan. 1903 and April 1905 deduced by averaging for the successive months the mean of the daily maximum and minimum tide gauge readings. Table XXXI contains the list of the monthly values obtained by averaging only the daily high tide levels, while Table XXIX gives the absolutely highest springs rise attained during the successive months.

After the recent great eruption of Sakura-jima, the tide observation at Kagoshima was resumed from Feb. 14th, 1914, in the same manner as before. Since May 1915, a self-recording tide-gauge apparatus, set up by the Department of the Interior at the inner side of the break-water of the harbour, is in the working order. As will be seen from the following §§, a comparison of the results of the above mentioned tide-gauge observations indicates a considerable elevation of the mean sea-level *relative* to the coast after the eruption in Jan. 1914.

43. Annual variation in height of mean sea-level. Before proceeding further, let us first consider the annual variation in the height of the bay-water surface previous to the eruption. According to Table XXV (based on Table XXX) and fig. 35, the mean sea-level at Kagoshima during 1903–1905 was lowest in February and highest in September, with the difference of 1.10 *shaku* (=33 cm); the amount and course of the annual variation in question being practically identical to those for Ōsaka. It is superflous to remark that the marked withdrawal of sea at the time of the spring tide in March is the effect of the low water combined to the depression of the mean sea-level in that part of the year. Again,

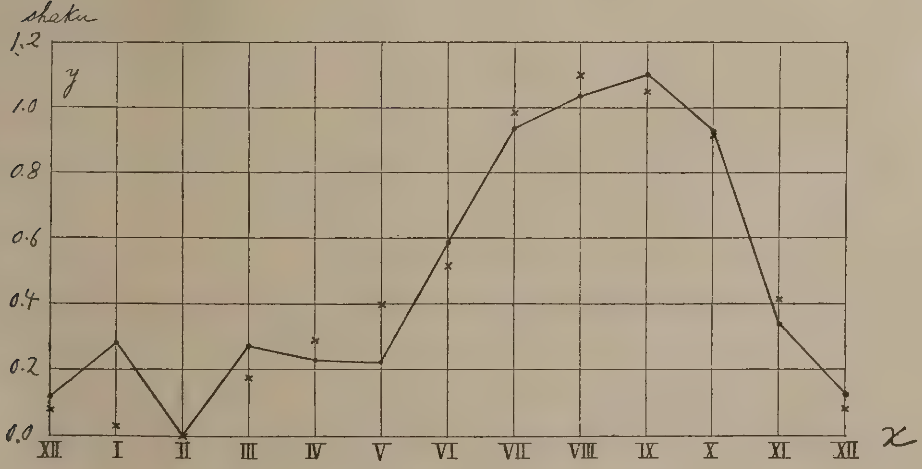

Fig. 35. Annual Variation of Mean Sea-level.

(•)....Kagoshima. (×)....Ōsaka.

y=mean height of sea-level corresponding to the month x, referred to that of February as zero. (1 *shaku*=30.3 cm=1 foot very nearly.)

the great flood tide in September, known in Japan as "hassak-jiwo"[*], is evidently the result of a spring tide, whose mean level corresponds to the maximum height of the sea surface in its annual variation. For the sake of reference, in Tables XXXII and XXXIII are given the mean monthly values respectively of the barometric pressure and the air temperature at the meteorological observatory of Kagoshima (height above sea-level=120 m) in 1903–5 and in 1914; the height of sea surface varying, on the whole, inversely to the barometric pressure and directly with the temperature.

TABLE XXV. MEAN MONTHLY SEA-LEVEL AT KAGOSHIMA PREVIOUS TO THE ERUPTION, COMPARED WITH THAT AT ŌSAKA.

Place. / Month.	Kagoshima. (1903—1905.)	Ōsaka. (1903—1912.)	Place. / Month.	Kagoshima. (1903—1905.)	Ōsaka. (1903—1912.)
	shaku	*shaku*		*shaku*	*shaku*
I	0.28	0.03	VII	0.94	0.99
II	0.00	0.00	VIII	1.03	1.10
III	0.27	0.18	IX	1.10	1.05
IV	0.23	0.29	X	0.93	0.91
V	0.22	0.40	XI	0.34	0.41
VI	0.59	0.54	XII	0.12	0.08

44. Apparent elevation of bay water level. In the northern part of the bay of Kagoshima the sea-level underwent an elevation relative to the coast, which became manifest first on the occasion of the spring tide on the 13th of March, 1914, when the tide-gauge indicated a rise of water to 12.2 *shaku*. This was much in excess of the high flood to be expected even in the autumnal "hassak-jiwo", and 2.1 and 1.5 *shaku* over the highest March sea-level in

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[*] Literally, tide on the 1st day of the 8th month of the year, in the old lunar calendar, corresponding to a new moon at the commencement of September.

1903 and that in 1904 respectively. The consequence was that, in the low districts about the mouth of the Kōtsuki-gawa at the S. end of the city, the ground was covered by sea water at the times of high tides. Along the N.W. and the N. parts of the coast of Kagoshima Bay, where the water rise was much greater, embankments and stone walls were damaged at several places, extensive rice fields being thereby devastated.

45. Highest monthly tide level in Kagoshima harbour. (See fig. 37.) Table XXIX gives a comparison of the highest monthly springs rise at the quay of Kagoshima harbour in the interval of Feb. 1914 to Jan. 1916, with that observed previous to the eruption, from Jan. 1903 to April 1905; the figures in the last column being the excess for the different months of the year of the former over the latter, or the apparent elevation of the high-water level after the eruption, approximately freed from the influence of the annual variation in the height of water.

According to Table XXIX, the excess of the high water level of spring tide after the eruption over that before it, which was slight in February 1914, was increased during the next 5 months from 1.3 to 1.8 *shaku*, with the mean of 1.46 *shaku*, reaching the maximum amount of 2.7 *shaku* in August of the same year. Since then, till the end of 1915, the difference remained mostly between 1.5 and 1.9 *shaku*, with the average of 1.6 *shaku*. The water level was highest in the months of August, September, and October, as follows:

13.5 *shaku*............................	in Aug. 1914.
13.1 „	Sept. 1915.
12.9 „	Oct. 1914.
12.7 „	Sept. 1914. Aug. 1915.

The apparent increase in the height of sea surface after the eruption in general, or the attainment of maximum elevation in August to October in particular, depended evidently on the elevation of the mean sea-level, and not on any increase in the range of the daily tidal oscillation or the vertical distance between the high and low waters, whose maximum monthly values, before and after the eruption, are given in the following table :—

TABLE XXVI. MAXIMUM DAILY TIDE RANGE IN KAGOSHIMA HARBOUR, BEFORE AND AFTER THE ERUPTION OF 1914.

Year. / Month.	Before the Eruption.		After the Eruption.		
	1903.	1904.	1914.	1915.	1916.
	shaku.	*shaku.*	*shaku.*	*shaku.*	*shaku.*
I	10.7	10.4	—	—	10.5
II	10.1	10.9	8.3*	9.7	
III	9.2	10.2	10.6	8.9	
IV	9.7	9.6	10.4	10.6	
V	10.2	9.8	—	10.2	
VI	10.1	10.0	—	10.0	
VII	10.6	10.1	—	9.8	
VIII	10.1	10.4	—	10.7	
IX	9.2	10.1	—	8.6	
X	9.1	9.9	—	9.6	
XI	9.0	9.6	—	10.0	
XII	9.9	9.6	—	10.3	

* Observation was re-started on the 14th of Feb. (1914).

From the above table it will be noticed in the first place that, according to the observation in 1903 and 1904, the daily range of tide in September and October, when the high water level reached the maximum limit of 11.3 *shaku*, was 9.1 to 10.1 *shaku*, being less than the corresponding amount of 10.1 to 10.9 *shaku* in January, February, June, July, and August. Again, in 1914 and 1915, the cases of maximum high-water elevation and the great daily tide range did not necessarily occur in one and the same month. Thus, in September 1915, the water surface reached an exceptionally high level of 13.1 *shaku*, while the maximum daily tide range was only 8.6 *shaku*.

46. Mean monthly sea-level in Kagoshima harbour. (See fig. 36.) In Table XXX are given the sea-surface heights for the successive months during the two years after the great eruption under consideration, obtained by averaging the means of the daily highest and lowest water levels. The values (bracketed in the list) for the interval of May 1914 to Jan. 1915 are imperfect, as the tide-gauge readings during these months were limited, except in the case of spring tides, to the day time and a few hours after dusk and before dawn.

The last column of Table XXX gives a list of the excess or elevation of the mean sea-level after the eruption over that for the corresponding month averaged from the heights in 1903-1905. During the first three months following the eruption the increase of the mean sea-level height was 1.42 to 1.30 *shaku*, with the mean of 1.37 *shaku*. The amount of elevation was 2.25 *shaku* in February 1915, thence slightly decreasing toward the end of the year. On the average the level elevation was augmented by about 0.75 *shaku* (=23 cm) in the course of one complete year after the eruption, being again decreased approximately by about 0.46 *shaku* (=14 cm) during the next 10 months as follows:—

Interval.	Amount of Level Change.	*Do.*, calculated (§ 51).
Feb. — April, 1914.	1.37 *shaku.*	— *shaku.*
Feb. — March, 1915.	2.12	2.11
April — June, „	1.81	1.90
July — Sep., „	1.61	1.71
Oct. 1915 — Jan., 1916.	1.66	1.52

Unfortunately the tide-gauge observation was not complete between May 1914 and Jan. 1915, but it is probable that the maximum limit of the level elevation at Kagoshima was some 3 *shaku* or about 0.9 m and reached between Aug. and Dec., in 1914.

47. Mean monthly high-water level in Kagoshima harbour. Table XXXI gives the mean highwater level deduced by averaging the maximum daily heights of sea surface for the different months, both before and after the eruption, namely, between Jan. 1903 and April 1905, and between Feb. 1914 and Jan. 1916. The mean amount of the level elevation after the eruption is approximately equal to those of the mean sea-level considered in the preceding §, being 1.42 *shaku* for Feb.–April in 1914, and 1.97 to 1.56 *shaku* in Feb. 1915–Jan. 1916, as follows:—

Time Interval.		Average Elevation.
1914:	Feb.—April,	1.42 *shaku.*
1915:	Feb.—April,	1.97
„	May—June,	1.82
„	July—Sept.	1.60
1915,	Oct.—1916, Jan.	1.56

48. Digression on sea-level variation at Hososhima. A remarkable change in the height of sea-level *relative* to the coast similar to that along Kagoshima Bay was not indicated at neighbouring districts, as will be seen from the following table, giving the yearly mean sea-level height for the 17 years, 1898 to 1914, at the tide-gauge station of Hososhima, in the province of Hyuga, about 134 km to the N.E. of Sakura-jima.

TABLE XXVII. MEAN YEARLY SEA-LEVEL* AT HOSOSHIMA, 1898—1914.
(IN METRE.)

Year.	Height of Sea-level.	Year.	Height of Sea-level.
	m		m
1898	(–) 2.554	1907	(–) 2.598
1899	538	1908	587
1900	556	1909	603
1901	564	1910	626
1902	575	1911	614
1903	555	1912	597
1904	576	1913	583
1905	554	1914	584
1906	574		

* Vertical distance of sea surface measured below a point fixed in the tide-gauge room.

It will be seen from the above table that the mean height of the sea-level in 1914 was not at all higher, but was, on the contrary, about 2 cm (=0.066 *shaku*) lower than in 1903 and 1904. Again, from Table XXVIII, giving for the 4 years 1911 to 1914 the mean monthly height of sea-level, it will be observed that the latter is subject in a given month of the year to a fluctuation of the maximum amount of 15 cm (=0.5 *shaku*). The amount of the level increase at Kagoshima (§ 46) was several times greater than this limit of fluctuation for Hososhima.

TABLE XXVIII. MEAN MONTHLY SEA-LEVEL AT HOSOSHIMA, 1911—14.

Vertical distance of sea surface measured below a point fixed in the tide-gauge room.

Year. Month.	1911.	1912.	1913.	Mean.	1914.
	metre.	*metre.*	*metre.*	*metre.*	*metre.*
I	2.765	2.720	2.666	2.717	2.816
II	2.828	2.661	2.667	2.719	2.718
III	2.651	2.688	2.722	2.687	2.613
IV	2.680	2.726	2.664	2.690	2.656
V	2.684	2.641	2.604	2.643	2.586
VI	2.563	2.513	2.491	2.522	2.539
VII	2.508	2.571	2.492	2.524	2.496
VIII	2.474	2.458	2.351	2.428	2.445
IX	2.435	2.416	2.473	2.441	2.404
X	2.482	2.546	2.485	2.504	2.498
XI	2.606	2.639	2.621	2.622	2.558
XII	2.688	2.585	2.762	2.677	2.677
Mean.	2.614	2.597	2.583	2.598	2.584

49. Change in sea-level height after Anei eruption, 1779. The eruption in the 8th year of Anei (1779) was also followed by the overflowing of sea-water along the coast of the bay of Kagoshima, as is evident from the following translation of an account by the famous traveller Tachibana Nankei, who visited the scene of disturbance about 4 years after the catastrophe :—" After the great eruption of Sakura-jima in the Anei period, the bay water was elevated 5 or 6 *shaku* at Kagoshima, and to over 10 *shaku* at some other places. The low strand streets, namely, Shimomachi, Tsukimachi, etc., of Kagoshima, were at times of spring tides covered by sea water, such that it was impossible to wade through even with high *geta* (wooden clog). The garden of the house of one Oyama Koemon, where I put up, was also on those cases filled with sea water. The efforts of the reighning lord of Satsuma to provide against the intrusion of sea water by the erection of embankments were ineffectual, and there were, in the neighbourhood of Kajiki, some villages entirely destroyed by tides or obliged to remove to higher grounds. The cause of the remarkable elevation of the sea surface may be in the depression of the ground of the two provinces of Satsuma and Ōsumi, in consequence of the outflow of rock and ash from Sakura-jima. Anyhow it was highly curious that the elevation of sea-level was limited to Kagoshima Bay." From the foregoing account it will be seen that the remarkable elevation of sea-level, whose maximum effect was shown in the neighbourhood of Kajiki, Kokbu, etc., on the northern coast of Kagoshima Bay, continued for, at least, 4 or 5 years after the great eruption of 1779. The subsequent course of the phenomena of elevation of the sea surface is not known, but, as stated in a subsequent §, it is probable that the sea-level regained its original height first after the lapse of several dozens of years.

50. Cause of sea-level elevation in Kagoshima Bay. The apparent or relative elevation of the sea-level attending the recent eruption of Sakura-jima (§§ 44–47) was of course not confined to the harbour of Kagoshima alone, but was manifested along the coast of Sakura-jima and of the northern portion of Kagoshima Bay, as was the case after the Anei eruption (§ 49). The maximum amount of the sea-level elevation was about 3 feet at Kagoshima, 3 to 4 feet at the vicinity of Shigetomi (about 14 km north of Kagoshima), and about 3½ feet at Kokbu and Kajiki; the change being also very marked at several places in Sakura-jima. Thus, at the village of Komen, situated on the north coast of the island, two houses which stood on the beach had to be removed in consequence of the increase in height of tides. Again, at the neighbouring village of Shirahama, the tide reached in Autumn of 1814 the house ground, whose side stonewall is 7 feet in height, and which is separated by a piece of cultivated field about 12 feet in width from the beach road now permanently under water. The vicinity of Nojiri at the S.W. part of the island also suffered much from a similar rise of the sea water. It seems that the maximum amount of sea-level elevation at Sakura-jima was some 2 metres and much greater than along the coast of Kagoshima Bay.

When the effect of the sea-level elevation became marked first in March 1914, the change was generally attributed to the closing of Seto Strait, which was believed to have much influence in impeding the tidal motion in the bay. Prof. A. Imamura supposed, however, the phenomenon in question to be the expansive effect of the bay water due to the heat communicated by the hot lava masses which flowed into the latter; while the present author attributed the elevation of the sea-level to the depression of the ground in and around Sakura-jima in consequence of the great eruption. That the influence both of the blocking up of Seto Strait and the heating of the water by the lava streams must have been very slight may be inferred from the fact that the amount of sea-level elevation immediately after the commencement of the eruption was much smaller than that 6 months later on. Further, the Anei eruption of Sakura-jima did not close Seto Strait, indicating that the blocking up of the latter, which probably modified to some extent the course of the current in the northern part of the bay, was not the necessary and sufficient cause of the sea-level elevation. Again, as will be seen form No. 3 of this Volume, the surface sea-water temperature in Kagoshima Strait on and about the 18th of January, 1914, one week after the commencement of the eruption, was 16°.7 C, or 1°½ C higher

Pl. XXVII.

3–1905.
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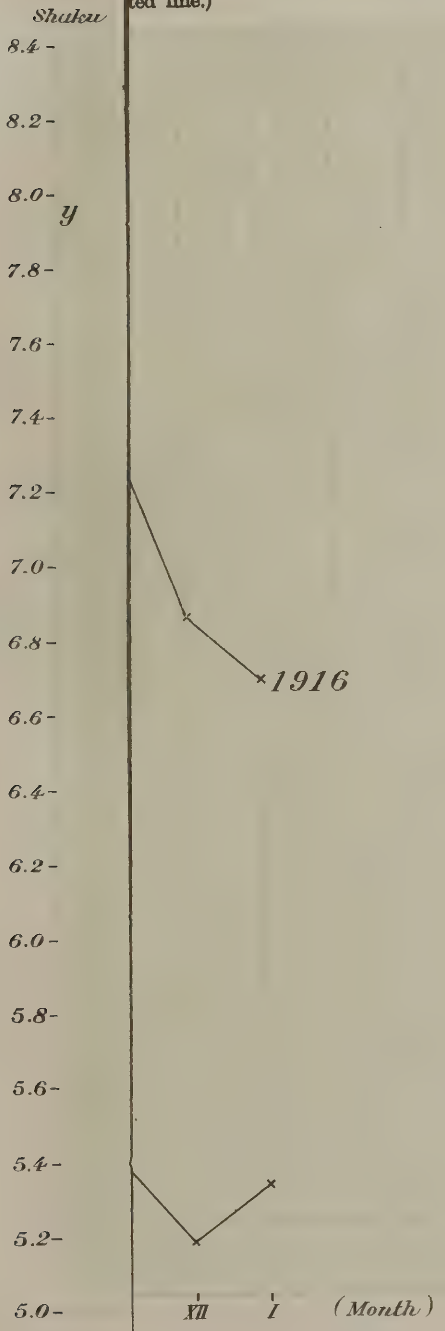
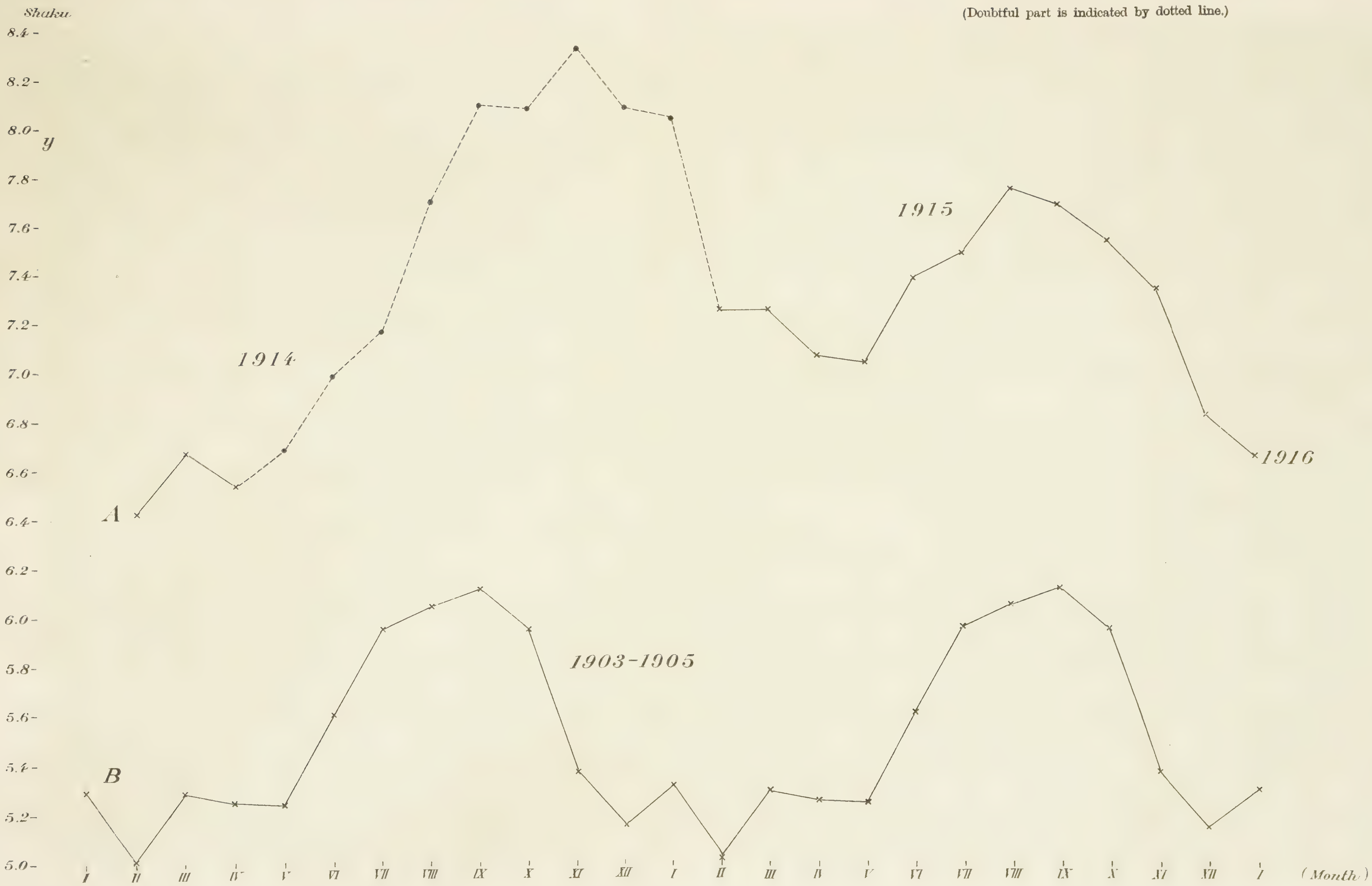


Fig. 36. Variation in Height of Mean Monthly Sea-level at Kagoshima, before and after the Sakura-jima Eruption of 1914.

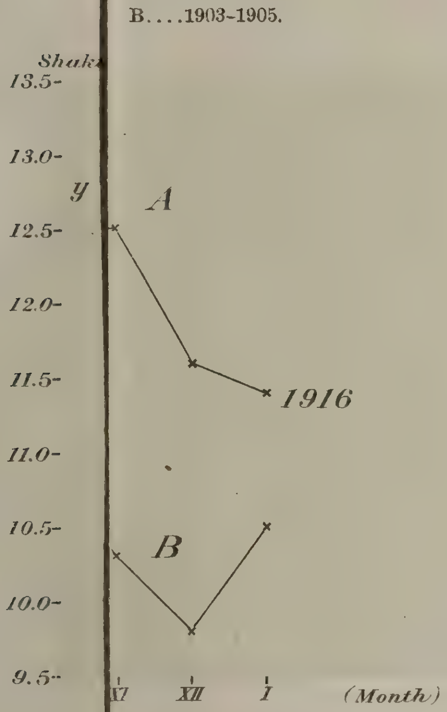
Pl. XXVII.

A....1914–1916. B....1903–1905.
(1 *shaku* = 30.3 cm = 1 foot very nearly.)

(Doubtful part is indicated by dotted line.)



Pl. XXVIII.



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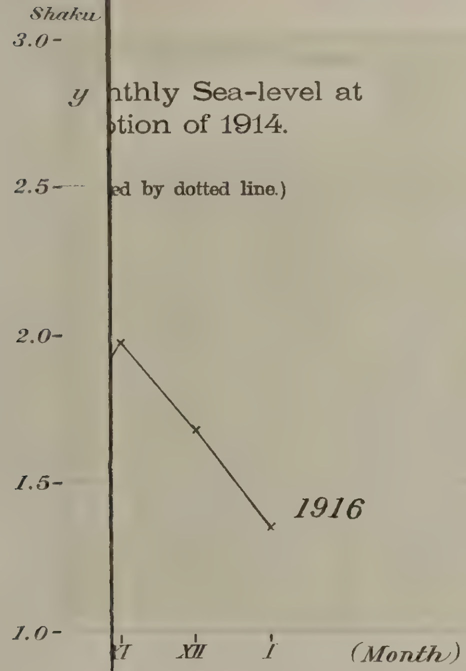
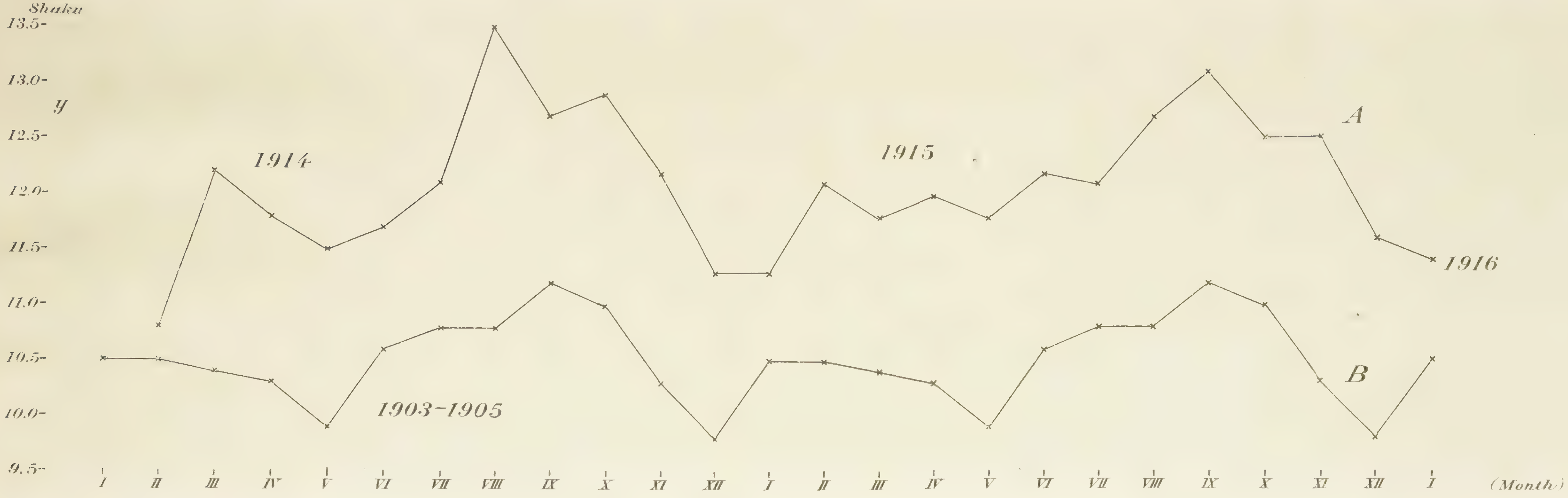


Fig. 37. Variation in the Maximum High-Water Level at Kagoshima during the Successive Months, before and after the Sakura-jima Eruption of 1914.

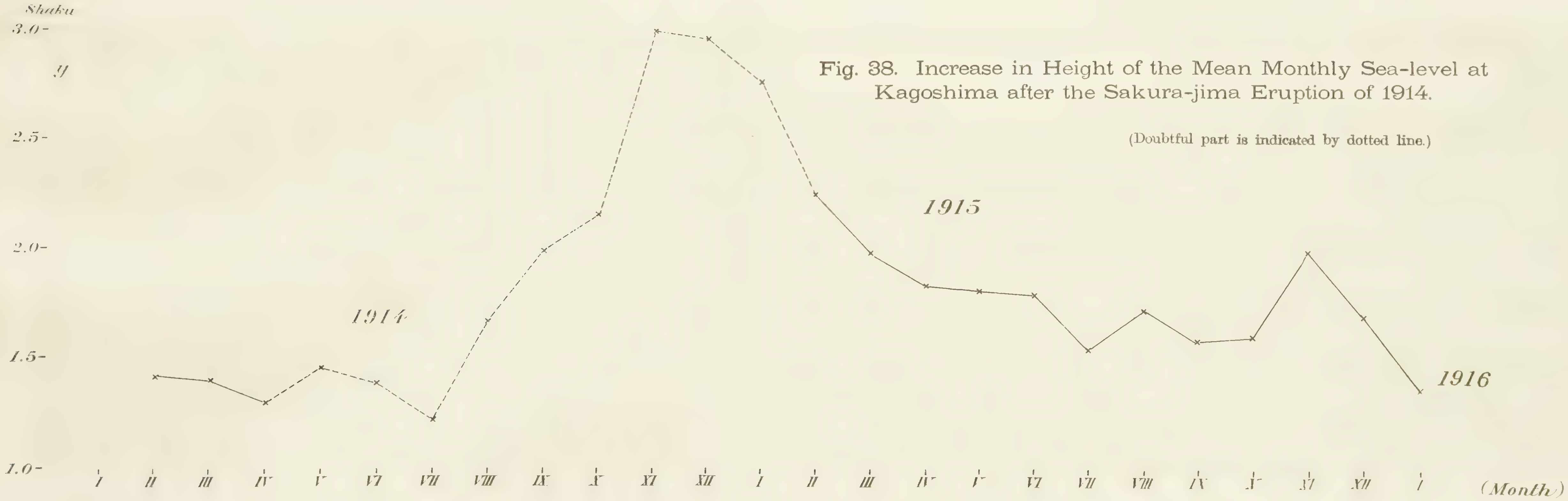
A....1914-1916. B....1903-1905.



(1 *shaku* = 30.3 cm = 1 foot very nearly.)

Fig. 38. Increase in Height of the Mean Monthly Sea-level at Kagoshima after the Sakura-jima Eruption of 1914.

(Doubtful part is indicated by dotted line.)



than that for the corresponding epoch in 1910–1912; the difference having, however, practically disappeared in the course of the further 3 months, namely, in and after April, 1914. That the eruption was followed by the depression of the ground, which was the real cause of the apparent sea-level elevation, will be seen from Chapter VII.

The restoration of the depressed level of the volcanic district to the original height may be followed by an elevation, as the result of the revival of the subterranean tension which would assert an upward pressure to the ground from below. In other words, the island of Sakura-jima and the neighbouring region may be supposed to execute a long-period oscillation in level change which follows the variation in the magnitude of the volcanic effort, an eruption taking place at the culmination of the elevation phenomenon. In fact, at Kagoshima and along the northern coast of the bay, the sea-water surface seems to have suffered a continual depression for half a century or so previous to the recent outbreak of Sakura-jima. Thus, 50 or 60 years ago at Hamano-ichi (濱之市), near Kokbu, the spring tide used to flood the low ground as far as the main road of the town, about 200 metres from the recent beach line. This, however, gradually ceased to be the case, the sea-level having since apparently been lowered, especially to a striking amount during a few years preceding the great outburst of Sakura-jima in 1914, such that the traffic in the small square harbour, about 250 m in extension, and almost dried up, had recently to be carried on with wagons instead of boats. Again, according to the account of Professor Tamari and others, the sea water had used to run up the rivers Inari-gawa (flowing through the northern part of the city of Kagoshima), Biu-gawa (別府川, near Shigetomi), and Shikine-gawa (near Shikine) 50 or 60 years ago through much greater distance than lately. All these facts evidently indicate an apparent recession of the sea-level, or the real elevation of the ground, which had began at the middle of the 19th century or at an earlier date, and became much pronounced immediately before the recent eruption. After the latter event, the sea-level have again been elevated.

The eruption of Jan. 12th, 1914, began at about 10 a.m., while the strong earthquake shock took place at 6.30 p.m. on the same day, the small "tsunami," or tidal waves, which occurred about 1 hour later on having probably been caused by the depression of the bottom ground. This might possibly mark the commencement of the phenomenon of the apparent sea-level elevation under consideration.

51. On future course of depression. As will be seen from §§ 45 and 46, the amount of the apparent sea-level elevation, or the depression of the ground, reached the maximum limit at the end of 1914. Its subsequent rate of decrease, namely, the reduction in the amount of the "sea-level elevation" with the increase of the time (x), may probably be assumed to be one of rectangular hyperbola, as is the case with the frequency variation of the after-shocks of a great earthquake, both relating to the recovery or settlement to the ordinary condition of equilibrium of a portion of the disturbed earth's crust. Making calculations from the mean values for the interval of Feb. 1915 to Jan. 1916, given at the end of § 46, we obtain the equation

$$y\,(x+23.04)-49.45=0,$$

in which y is expressed in *shaku*, and x in months, whose origin of reckoning ($x=o$) corresponds to February 1915. According to the above relation, the value of y would be reduced to 0.5 *shaku*

(=15 *cm*) in $x=76$ months, and to 0.1 *shaku* (=3 *cm*) in $x=472$ months, that is to say, respectively about 7 and 40 years after the commencement of the eruption in Jan. 1914. These estimations, though very roughly approximate, seem to indicate that the depression of the relative sea-level, or the elevation of the ground, to the position just before the eruption would take yet several dozens of years, a conclusion well in accord with what has been stated in the preceding §. In Fig. 39, the broken line relates to the actual mean increase of the sea-level height, while the dotted curve has been drawn according to the empirical equation above obtained.

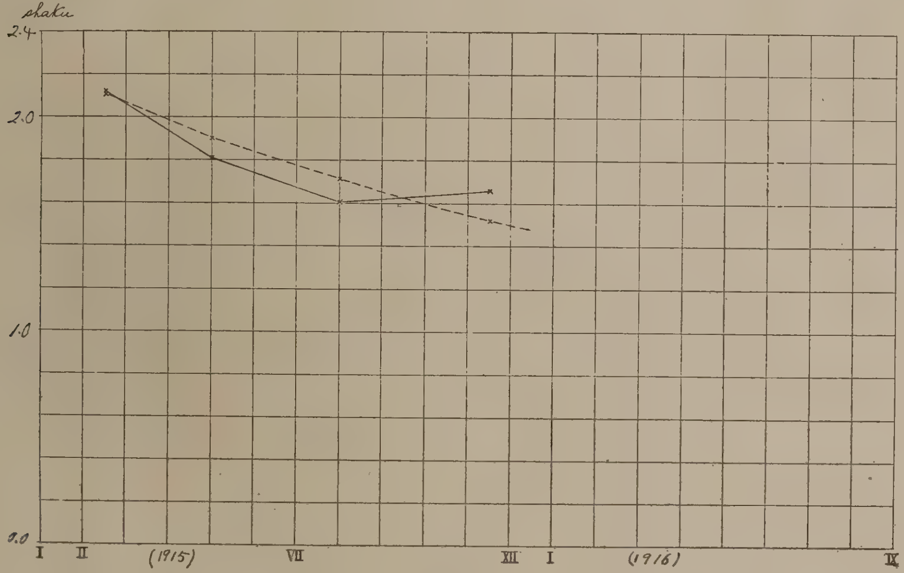


Fig. 39. Gradual Reduction since the commencement of 1915 in the Height of the Elevated Mean Sea-level at Kagoshima.

(1 *shaku* = 30.3 cm = 1 foot very nearly)

TABLE XXIX. HIGHEST SEA-WATER LEVEL IN KAGOSHIMA HARBOUR BEFORE AND AFTER THE SAKURA-JIMA ERUPTION OF 1914.

Year. / Month.	Before the Eruption.				After the Eruption.	Difference.
	1903.	1904.	1905.	Mean.	1914–16.	
				1903–5	**1914**	
	shaku.	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*
I	11.2	9.8	10.4	10.5	—	—
II	11.0	10.3	10.3	10.5	10.8	0.3
III	10.1	10.7	10.5	10.4	12.2	1.8
IV	10.0	10.2	10.6	10.3	11.8	1.5
V	10.0	9.7		9.9	11.5	1.6
VI	10.6	10.5		10.6	11.7	1.1
VII	10.7	10.8		10.8	12.1	1.3
VIII	10.6	11.0		10.8	13.5	2.7
IX	11.1	11.3		11.2	12.7	1.5
X	10.7	11.3		11.0	12.9	1.9
XI	10.3	10.2		10.3	12.2	1.9
XII	9.7	9.9		9.8	11.3	1.5
				1903–5	**1915**	
I				10.5	11.3	0.8
II				10.5	12.1	1.6
III				10.4	11.8	1.4
VI				10.3	12.0	1.7
V				9.9	11.8	1.9
VI				10.6	12.2	1.6
VII				10.8	12.1	1.3
VIII				10.8	12.7	1.9
IX				11.2	13.1	1.9
X				11.0	12.5	1.5
XI				10.3	12.5	2.2
XII				9.8	11.6	1.8
				1903–5	**1916**	
I				10.5	11.4	0.9
II				10.5		

TABLE XXX. MEAN MONTHLY HEIGHT OF SEA-LEVEL IN HARBOUR OF KAGOSHIMA BEFORE AND AFTER THE SAKURA-JIMA ERUPTION OF 1914.*

Year. / Month.	Before the Eruption.				After the Eruption.	Sea-level Elevation.
	1903.	1904.	1905.	Mean.	1914–16.	
				1903–5	**1914**	
	shaku.	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*
I	5.81	4.85	5.19	5.29	—	—
II	—	5.04	4.98	5.01	6.43	1.42
III	5.36	5.38	5.10	5.28	6.68	1.40
IV	5.15	5.26	5.31	5.24	6.54	1.30
V	5.24	5.22		5.23	(6.69)	(1.46)
VI	5.54	5.66		5.60	(6.99)	(1.39)
VII	5.85	6.04		5.95	(7.17)	(1.22)
VIII	5.78	6.29		6.04	(7.71)	(1.67)
IX	5.93	6.29		6.11	(8.11)	(2.00)
X	5.93	5.95		5.94	(8.10)	(2.16)
XI	5.35	5.35		5.35	(8.35)	(3.00)
XII	5.12	5.13		5.13	(8.10)	(2.97)
				1903–5	**1915**	
I				5.29	(8.06)	(2.77)
II				5.01	7.26	2.25
III				5.28	7.26	1.98
IV				5.24	7.07	1.83
V				5.23	7.04	1.81
VI				5.60	7.39	1.79
VII				5.95	7.49	1.54
VIII				6.04	7.76	1.72
IX				6.11	7.69	1.58
X				5.94	7.54	1.60
XI				5.35	7.34	1.99
XII				5.13	6.82	1.69
				1903–5	**1916**	
I				5.29	6.65	1.36
II				5.01		

* Figures within brackets are only roughly approximate.

TABLE XXXI. MEAN MONTHLY HIGH-TIDE LEVEL IN HARBOUR OF KAGOSHIMA BEFORE AND AFTER THE SAKURA-JIMA ERUPTION OF 1914.*

Year. Month.	Before the Eruption.				After the Eruption.	Difference.
	1903.	1904.	1905.	Mean.	1914–16.	
				1903–5	**1914**	
	shaku.	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*
I	9.29	8.33	8.70	8.77	—	—
II	—	8.48	8.40	8.44	(9.85)	1.41
III	8.68	8.78	8.42	8.63	10.08	1.45
IV	8.45	8.58	8.57	8.53	9.92	1.39
V	8.57	8.63		8.60	(9.82)	(1.22)
VI	8.98	9.06		9.02	(10.20)	(1.18)
VII	9.26	9.40		9.33	(10.37)	(1.04)
VIII	9.08	9.58		9.33	(10.85)	(1.52)
IX	9.15	9.61		9.38	(11.00)	(1.62)
X	9.14	9.30		9.22	(10.77)	(1.55)
XI	8.67	8.78		8.73	(10.49)	(1.76)
XII	8.60	8.62		8.61	(9.80)	(1.19)
				1903–5	**1915**	
I				8.77	(10.25)	(1.48)
II				8.44	10.41	1.97
III				8.63	10.55	1.92
IV				8.53	10.54	2.01
V				8.60	10.46	1.86
VI				9.02	10.80	1.78
VII				9.33	10.77	1.44
VIII				9.33	11.07	1.74
IX				9.38	11.01	1.63
X				9.22	10.78	1.56
XI				8.73	10.63	1.90
XII				8.61	10.07	1.46
				1903–5	**1916**	
I				8.77	10.08	1.31
II				8.44		

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* Figures within brackets are only roughly approximate.

TABLE XXXII. MEAN MONTHLY BAROMETRIC PRESSURE AT KAGOSHIMA. (Reduced to 0°C.) 1903–5; 1914.

Year. / Month.	1903.	1904.	1905.	Mean.	1914.
I	755.7	757.8	753.4	755.6	756.83
II	756.7	755.6	753.9	755.4	754.74
III	752.4	752.6	754.0	753.0	752.99
IV	752.2	753.0	751.6	752.3	751.14
V	751.2	749.5	750.9	750.4	750.26
VI	746.5	748.5	746.1	747.5	747.96
VII	747.6	747.1	747.7	747.4	747.55
VIII	750.3	746.9	747.7	748.6	746.13
IX	750.1	749.0	751.4	749.6	749.67
X	751.9	752.7	753.2	752.3	754.49
XI	755.3	755.6	756.0	755.5	755.38
XII	756.2	756.6	755.3	756.4	755.82
Mean.	752.2	752.1	751.8	752.2	751.91

TABLE XXXIII. MEAN MONTHLY AIR TEMPERATURE AT KAGOSHIMA. 1903–5; 1914.

Year. / Month.	1903.	1904.	1905.	Mean.	1914.
I	8°.0 C	6°.1 C	9°.9 C	8°.0 C	7°.68 C
II	7.8	8.7	6.3	7.6	8.85
III	13.1	10.9	10.9	11.6	12.95
IV	15.8	16.6	14.8	15.7	14.65
V	17.8	18.4	18.9	18.4	19.76
VI	20.4	22.0	22.3	21.5	22.70
VII	23.8	26.2	25.8	25.3	27.57
VIII	27.1	26.4	25.2	26.2	26.99
IX	24.6	23.3	23.3	23.7	24.39
X	19.1	18.8	19.0	19.0	19.02
XI	13.0	11.9	14.5	13.1	14.91
XII	7.6	9.1	11.9	9.5	9.65
Mean.	16.5	16.5	16.9	16.6	17.43

CHAPTER VII. LEVEL CHANGE AND HORIZONTAL DISPLACEMENT OF THE GROUND CAUSED BY THE SAKURA-JIMA ERUPTION OF 1914.

52. Precise leveling. The first Military Survey precise leveling in the S.W. part of Kyushu, from the tide gauge station of Hososhima (province of Hyuga) to the cities of Kagoshima (province of Satsuma) and Sashiki (province of Higo) were carried on 20 to 22 years before the recent Sakura-jima outburst, namely, between Dec. 1891 and Jan. 1895, and was supplemented with the measurements at the N.W. coast of Kagoshima Bay in 1900. After the eruption, to investigate the phenomenon of the apparent elevation of the sea-level which became manifest in March (1914), the Imperial Earthquake Investigation Committee requested the Military Survey to make a new determination of the heights of the different bench-marks about Kagoshima Bay. This was readily responded to in a very complete manner, and the re-examination of the levelings was executed in 1914–15, in the following order:—

(i) July and August, 1914. A distance of about 22 km from Ijuin (B.M. 2457) at the middle of the Satsuma peninsula to the city of Kagoshima (B.M. 2468); then a distance of about 104 km along the coast of the N. part of Kagoshima Bay (B.M. 2468 to B.M. 2794, and thence to B.M. 2512).

(ii). Dec. 1914 to Jan. 1915. From the N.E. corner of Kagoshima Bay (B.M. 2794) along the total distance of 157 km, through the city of Miyasaki up to the tide gauge station of Hososhima, in the province of Hyuga.

(iii) Feb. 1915. Again, through the distance of 49 km from the city of Kagoshima (B.M. 2468) along the coast to the N.E. corner of the bay (B.M. 2794).

(iv) Feb. to May, 1915. From Ijuin (B.M. 2457) along the N.W, coast of the peninsula of Satsuma, through a length of about 83 km, to Sashiki, in the province of Higo (B.M. 2865).

According to the first leveling survey, in which the B.M. 2457, at the town of Ijuin in the middle of the Satsuma peninsula, was assumed to have suffered no height alteration, the B.M. 2469, in the city of Kagoshima, was found to have been depressed 0.24 m. The tide gauge reading at the Kagoshima harbour, however, indicated already in March-April 1914 an apparent increase in the height of sea-level of 0.4 metre over that in the corresponding months in 1903–1905, or about 0.16 m greater than the amount of the depression of the ground above mentioned. Hence the Ijuin B.M. 2457 could not be regarded as a steady point, and the 2nd leveling measurement was resumed in Dec. 1914 and Jan. 1915, connecting Kagoshima Bay with the tide gauge station of Hososhima far up on the E. coast of Kyushu. As the result of this extensive survey referred to the old measurements in Dec. 1894 and Jan. 1895, it was established that, in July and August, 1914, the depression of the Ijuin B.M. 2457 itself amounted to 0.165 m, and consequently the depression of the B.M. 2469 in the Kagoshima city to 0.407 m. The 4th series of leveling observations connected Ijuin with Sashiki on the W. coast of the province of Higo. The results of the 1st, 2nd, and 3rd surveys are given in Tables XXXVIII and XL.

53. Works done by Government Kyushu Railways. At the present author's request, Mr. H. Nagao, Director of the Kyushu Imperial Government Railways, also instituted the re-examination of the heights of the different bench-marks set up along the railway lines about Kagoshima Bay; the surveys having been carried on between April 4th and May 15th, 1915, for a length of 41 miles on the main line from Yoshimatsu to Kagoshima, and of 19 miles from the latter city to the Yunomoto station on the Sendai line. The dates of the previous leveling measurements, with which the results of the new determinations have been compared, are as follows :—

Yoshimatsu-Kokbu	Section........	July 1899 to May 1900.
Kokbu-Kagoshima	,, ...	Sept. 1897 to May 1898.
Kagoshima-Yunomoto	,, ...	July 1912 to July 1913.

The new levelings of the bench-marks along the length of 6 miles between Yoshimatsu and the next southward station of Kurino indicated only a height difference under ½ inch (=1⅕ cm) when compared to the results of those made in 1911, which amount may be regarded to be within the error of the survey. Consequently the station of Yoshimatsu may be regarded to have been practically unchanged in height before and after the recent eruption of Sakura-jima.

It will be observed that the Kyushu Government Railways' survey between Kokbu and Yoshimatsu supplements the works of the Military Survey for a length of about 27 miles northwards from the north coast of Kagoshima Bay. As will be seen from the following table, which gives the amount of the depression of the different railway stations within the region under consideration and the neighbouring bench-marks, the results obtained by the Kyushu Gov. Railways, though probably inferior in accuracy to those of the Military Survey, are fairly trustworthy. The graphical illustrations are given in fig. 45.

TABLE XXXIV. HEIGHT CHANGES ALONG KYUSHU RAILWAY LINES.

Railway Line.	Bench-Mark or Station.	Amount of Depression* according to Leveling Survey of	
		Kyushu Gov. R.	Mil. Survey.
Main Line.	Mil. Survey B.M., 2481	−620$^{\text{mm}}$	−577$^{\text{mm}}$
	Kajiki Station.	−600	——
	Mil. Surv. B.M., 2480	−565	−560
	„ 2479	−554	−536
	„ 2477	−630	−608
	Shigetomi Station.	−685	——
	Mil. Surv. B.M., 2476	−715	−703
	„ 2475	−761	−776
	„ 2474	−852	−894
	„ 2473	−745	−770
	„ 2472	−649	−658
	„ 2471	−496	−527
	„ 2470	−402	−446
	Kagoshima Station.	−353	——
	Mil. Surv. B.M., 2469	−347	−407
Sendai Line.	Take Station.	−231	——
	Manjuishi Station.	−103	——
	Ijuin Station.	+ 9	——
	Kyushu Gov. Railways B.M., 29	− 3	——
	Mil. Surv. B.M., 2456	− 49	−126
	„ 2455	− 55	−150

* −, when depressed; +, when elevated.

51. Discrepancy between amounts of ground depression and apparent sea-level elevation. According to the leveling measurements of the Mil. Survey, the depression since Feb. 1892 of the B.M. 2469 on the strand street of Kagoshima amounted to 0.407 metre in July

1914, which was increased to 0.411 metre in Feb. 1915. According to the tide gauge observations, however, the mean sea-level in the latter month was 2.25 *shaku*, or 0.682 metre, higher than in the corresponding month in 1903–1905. (See § 46.) Similarly, the apparent elevation of the mean sea-level during the four subsequent months, March to June, 1915, was 0.185 *shaku*, or 0.561 metre. Again, the height increase of the spring-tide flood level in March to December, 1914, varied mostly from 1.5 *shaku* =0.455 metre to 2.9 *shaku* =0.85 metre (§ 45), with the average of 1.68 *shaku* or 0.51 metre, which may be regarded as approximately representing the amount of increase in the height of mean sea-level for the two middle months of the year, namely, July and August, 1914. It thus seems that the height increase of the mean sea-level, which, of course, might have been influenced by various circumstances, was some 0.15 metre greater than the amount of the depression of the ground brought out by the leveling survey. As, however, the tide range after the eruption was identical with that before it (§ 45), there is to be assumed no special irregularity of the tidal motion in the bay, which might produce such an elevation of sea surface over the amount due to the depression of the ground. On the contrary I believe the

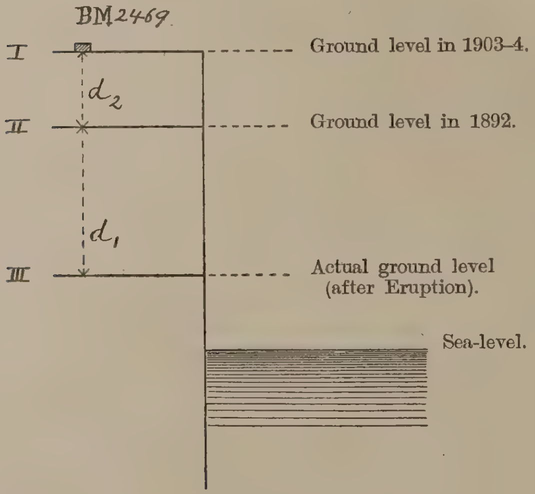


Fig. 40. Diagram illustrating the relation of the heights of sea-level at Kagoshima after and immediately before the eruption of 1914 to that in 1894.

apparent elevation of the sea-level to be entirely due to the depression of the ground, the discrepancy in the results of the two measuring processes being caused by the gradual elevation of the ground level for several years preceding the recent eruption. Thus, the ground surface (B.M. 2469), which was in the level II (fig. 40) in 1892, occupied an elevated position I in 1903–4, but was lowered to the position III after the recent eruption. If d_2 be the elevation of the ground since 1892, and d_1 be the depression of the ground after the eruption compared to the position in the same year, and if r_2 and r_1 be the tide gauge reading respectively after the eruption and in 1903–4, we have :—

$$r_2 - r_1 = d_1 + d_2$$

In other words, the apparent elevation of sea-level $(=r_2-r_1)$, is greater than the depression of the ground $(=d_1)$ referred to 1892 ; the difference between these two, namely, d_2, denoting the amount of the elevation of the ground between 1892 and 1903–4. (See also § 49.) In the following table, the means of the daily highest and lowest tide levels during the 31 days, from May 12th to June 12th, in 1909, when the tide gauge readings were made for some special purpose, are compared with those in 1903 and 1904. It follows that the apparent May-June sea-level in 1909 was about 0.2 *shaku* =0.06 metre lower than that in 1903–4, tending to indicate that the ground was being elevated before the eruption.

TABLE XXXV. MEAN DAILY HEIGHT OF SEA-LEVEL AT KAGOSHIMA.

May–June, in 1903–4 and 1909.

Year. / Date.	1903.	1904.	1909.	Year. / Date.	1903.	1904.	1909.
	shaku	*shaku*	*shaku*		*shaku*	*shaku*	*shaku*
May 12	5.0	5.6	5.2	May 28	4.9	5.4	5.3
13	5.5	5.3	5.6	29	5.0	5.3	5.2
14	5.3	5.0	5.5	30	5.0	5.3	5.4
15	5.2	5.0	5.7	31	5.1	5.2	4.9
16	5.1	4.9	6.1	June 1	5.2	5.1	5.0
17	5.1	5.0	5.5	2	5.6	5.3	4.8
18	5.4	4.8	5.4	3	5.8	5.5	4.8
19	5.4	4.9	5.4	4	5.8	5.8	4.9
20	5.5	5.2	5.0	5	5.5	6.0	4.9
21	5.7	5.4	4.8	6	5.3	6.3	4.8
22	5.6	5.4	4.7	7	5.3	6.4	4.8
23	5.4	5.6	4.7	8	5.1	6.4	5.0
24	5.3	5.7	4.8	9	5.1	5.8	5.1
25	5.0	5.5	5.2	10	5.1	5.6	5.2
26	5.0	5.5	5.5	11	5.0	5.8	5.3
27	4.9	5.4	5.5	12	5.0	5.7	5.9
				Mean...........	5.37		5.18

55. Depression of ground about Sakura-jima. In fig. 42, which embodies all the results of the leveling surveys made by the Military Survey contained in Table XL as well as those of the Kyushu Gov. Railways for the Yoshimatsu-Kokbu section, the curves of depression of 50, 100, 300, and 500 mm, have been drawn by interpolations. In the first place, it will be noticed that for a time interval of 21 years between 1894 and 1915 there was no change, or there has been a slight depression of the ground less than 50 mm, for a length of about 135 km from the tide gauge station of Hososhima on the coast of Hyuga till within the N.E. boundary of the province of Ōsumi, at a distance of only about 15 km from the N.E. coast of Kagoshima Bay. On the contrary, to the N.W. of Sakura-jima there have been depressions of the ground to the amount of about 100 mm along the N.W. coast of Satsuma, and continued to the town of Sashiki, in the province of Higo, where the leveling re-examination ended; it being likely that the depression extends further some distance to the sea bottom area to the west of Kyushu. The entire amount of the depression in the last mentioned region may not be due directly to the recent eruption of Sakura-jima.

The two depression lines of 300 and 500 mm run close to the coast of the N. portion of Kagoshima Bay, having a comparatively greater landward extension in the N. and W. directions. These two curves have more or less definitely two axes of symmetry in the directions respectively of E.-W. and N.N.E.-S.S.W. The point of their intersection, which may be regarded as indicating the position of the locality of the greatest depression of the ground, is under the sea to the N. of Sakura-jima, off the coast of Shirahama.

The dimensions of the different lines of equal depression are as follows:—

500 mm Curve: Min. Diameter=13½ km; Max. Diameter=20 km.
300 „ : Min. Diameter=19 km; Max. Diameter=25 km.
100 „ : Min. Radius=14 km; Max. Radius=32 km.
50 „ : Min. Radius=17 km.

Again, the areas enclosed within the different lines of equal depression are as follows:—

Area within the 500 mm Curve=477 sq. km.
Area between the 500 and 300 mm Curves=236 sq. km.
„ „ „ 300 and 100 mm „ =2610 „ (*apprx.*).

The total area enclosed by the 100 mm curve is about 3370 sq. km. The form of the deformed earth surface along the E.-W. diameter will be approximately as is illustrated in fig. 41, in which the maximum amount of the depression is assumed to be at least 3 metres, this supposition being probable enough according to what has been stated in § 58. The approximate volumes of depression are as follows :—

Depression Volume within the 500 mm Curve	0.64	c. km.
„ „ between the 500 and 300 mm Curves	0.11	„
„ „ „ „ 300 and 100 mm „	0.52	„

The depth of the depression considered above, which is based

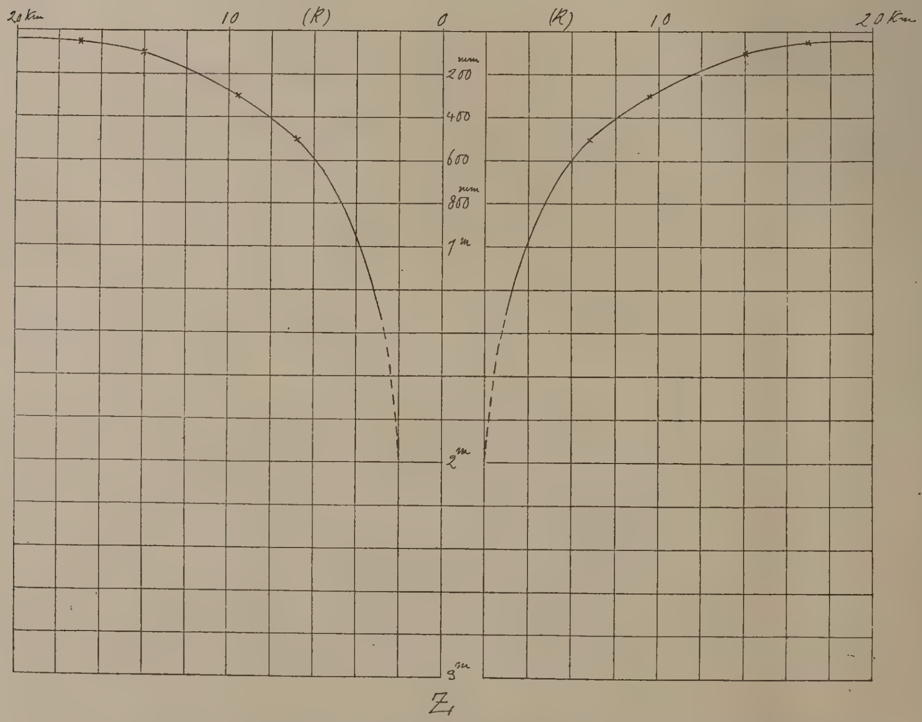
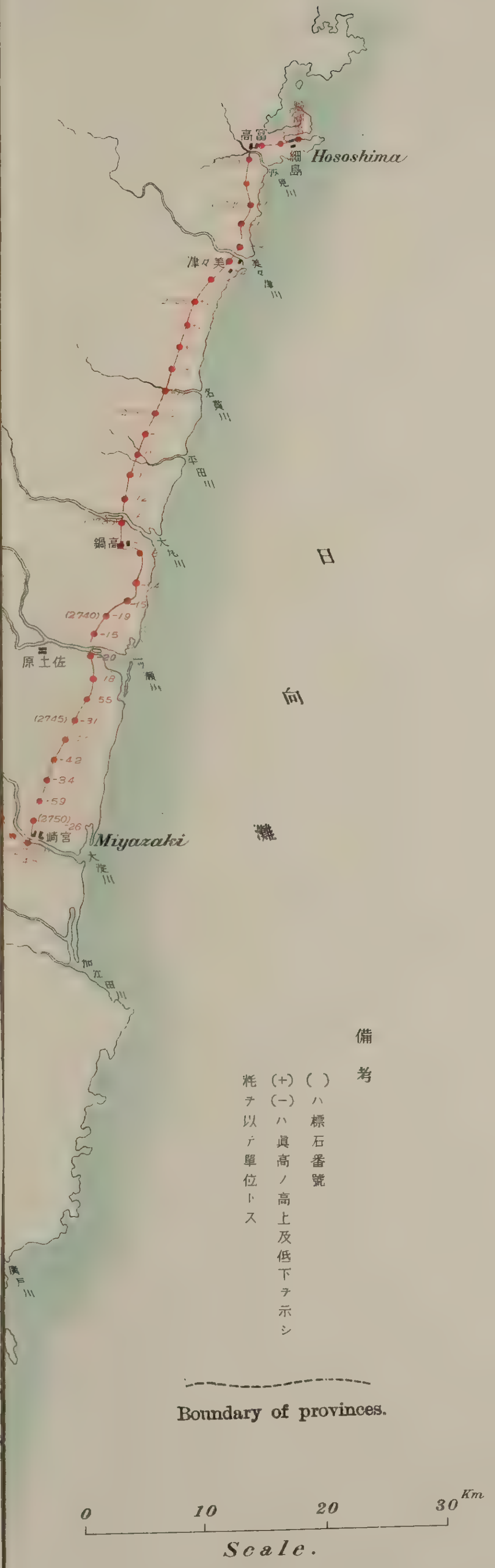


Fig. 41. Level Change caused by Sakura-jima Eruption of 1914: Section representing the amount of Depression of the ground in an E.W. direction at varying radial distances (R) from the centre. Depression is measured downwards along the axis oz.

Pl. XXIX.

-Marks in
1914.



Curves are lines of equal depression respectively of 500; 300; 100; and 50 mm. The figures in red denote the height change: (−), depression; (+), elevation. The number enclosed in brackets is that of a B.M.

Fig. 42. Map showing the Differences in Height of the Bench-Marks in S. Kyushu before and after the Sakura-jima Eruption of 1914.

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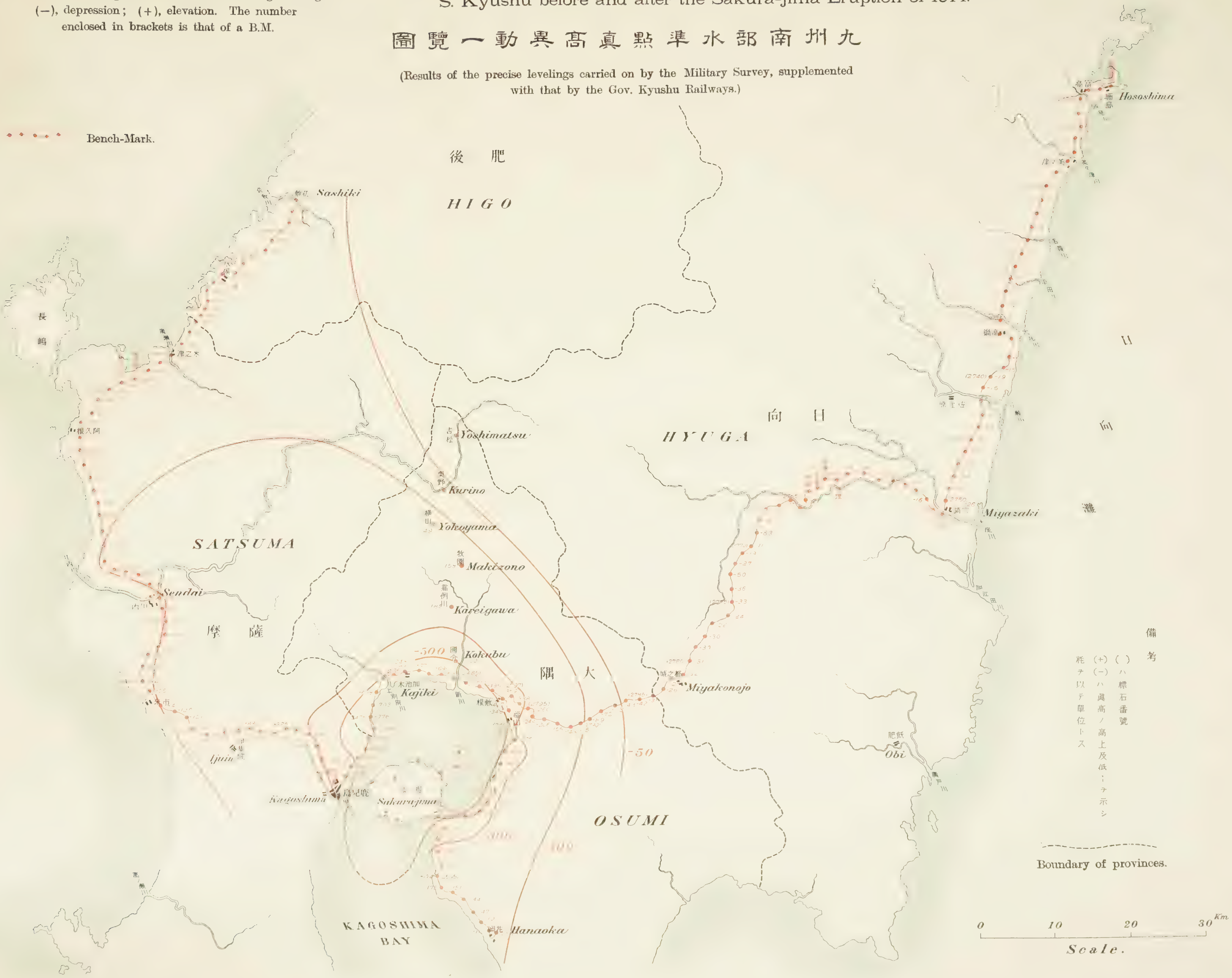
(Results of the precise levelings carried on by the Military Survey, supplemented with that by the Gov. Kyushu Railways.)



simply on the results of the leveling surveys, must be increased by about 0.15 metre (§ 54), at least for the 500 mm curve, to bring the estimation up to the condition immediately previous to the eruption of 1914. This gives 0.82 c. km for the total depression volume within the 300 mm curve, and 1.35 c. km for that within the 100 mm curve. As a portion of the depression between the 300 and 100 mm curves may be supposed to be also the effect of the eruption, we may take 1 c. km, in round number, for the approximate total depression volume due to the latter. This is within a quite reasonable limit, being a little less than half of the aggregate volume, =2.2 c. km , of the lava outflows and the pumice and ash ejection in the recent eruption.

The position of the point of the maximum depression, which lies under the sea to the north of Sakura-jima, probably coincides with that of the principal centre of the underground lava reservoir. The latter, as a whole, may extend under the area including the northern part of Kagoshima Bay and the surrounding tract, where the depression of the ground has been more or less marked, or an irregular circle about 45 km in diameter. It is likely that the particular portion of the lava reservoir, which supplies magma to the two active volcanoes of Sakura-jima and Kirishima, are situated not necessarily under these volcanoes themselves, but rather at the region midway between them, which thus ought to be a place specially sensitive to the subsidence. The existence of the lake of Toya behind Usu, of the lake of Shikotsu behind Tarumai, (both in Hokkaido), and of the lake of Ikeda behind Kaimon (Satsuma) seem to be the result of some analogous relation of the position of the lava reservoir and the actual eruptive vent.

56. On the limit of subsidence. For the sake of reference, let us see first what took place, in connection with the subject of the subsidence, on the occasion of the several recent outbursts of Ōshima (Izu) and Asama. In the case of the latter volcano, the molten lava mass at the bottom of the crater, whose previous depth was 120 m, was gradually elevated through a vertical distance of about 100 m, until at the end of 1911, when the eruptive action reached its climax, it was almost on the point of flowing out and running down the mountain slope. Since then, in consequence of the decline of the volcanic activity, the crater bottom began to be depressed, so that at the present time it is at a depth of some 80 m. Again, in the Ōshima eruptions of March–April and Sept.–October, 1912, the lavas which flowed out at the crater bottom, accumulated to heights respectively of 33 and 63 m above the original plane of the latter. After the end of these eruptive epochs, however, remarkable subsidences took place, whereby the central portion of the lava area fell down through the vertical distances of 30 to 60 m, leaving behind terraces along the inner base of the crater wall. From examples like these, it seems natural that a settlement of the Sakura-jima district should follow the exceptionally abundant recent outflow of lava and emission of ash and pumice, whose aggregate amount is equal to 1/12th of the total volume of the island, and which, if distributed uniformly over the whole area of the latter, would have a thickness of about 31 m. Even supposing the extension of the lava reservoir to be great, it seems inevitable that there should be formed a vacant cavity underneath, or, at the least, a space filled with comparatively loose rocky material, such that the volcanic region in question would form virtually a sort of a rocky arch or bridge over the inside magma; its vertical deflection, which constitutes the subsidence phenomenon, reaching a certain limiting amount, after which a recovery ought to take place, provided the volcanic force happen again to be augmented.

Sakura-jima marks the

d 1 metres.

Pl. XXX.

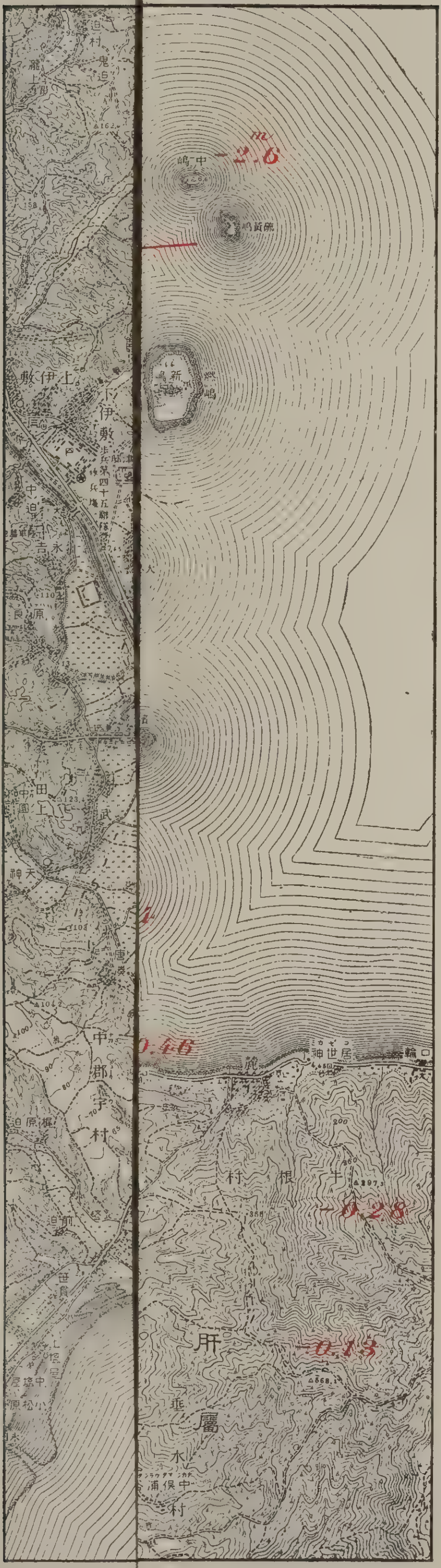


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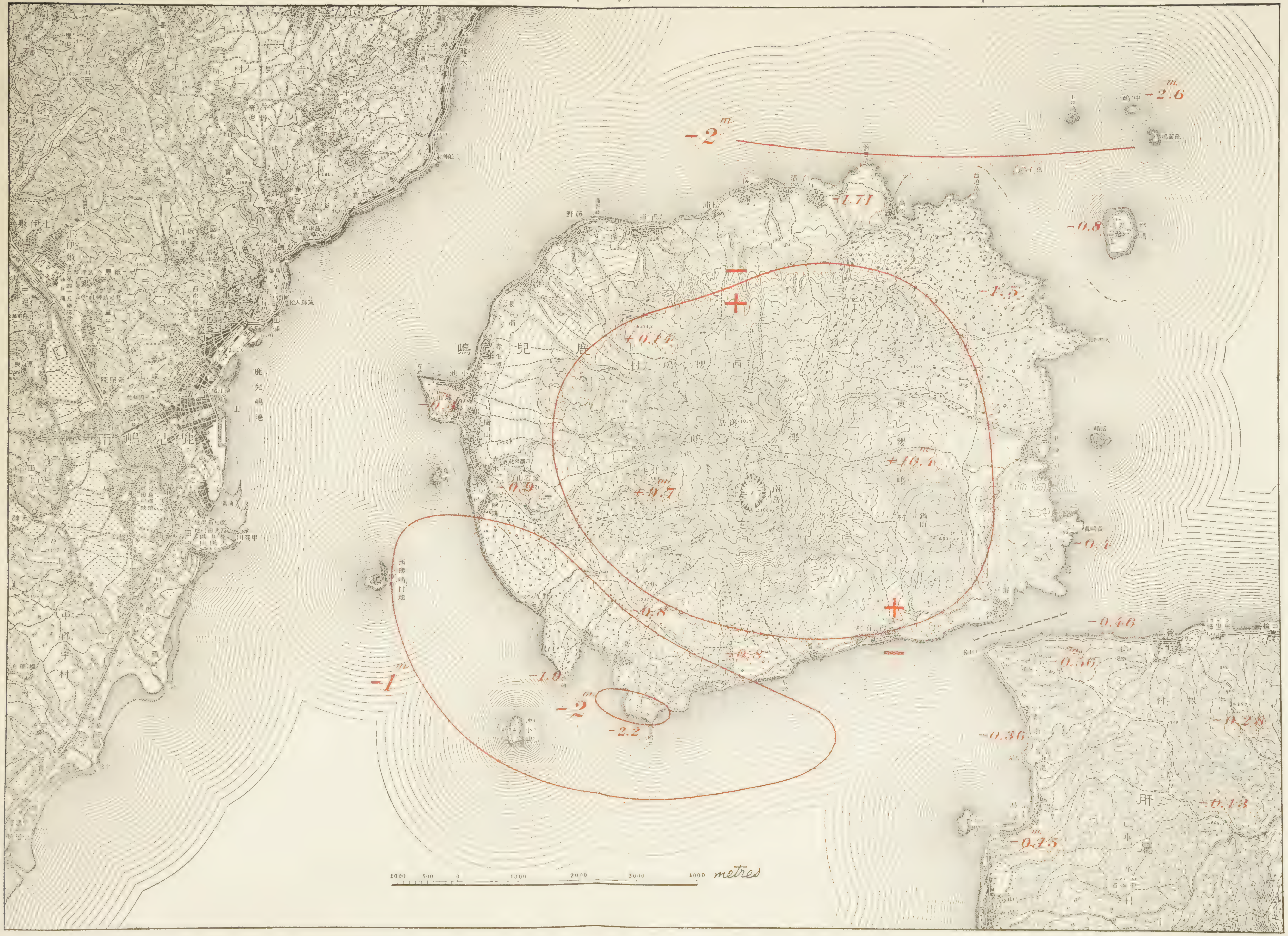
Fig. 43 Map showing the Depression and Elevation of the Ground produced in Sakura-jima and Vicinity after the Eruption of 1914.

(Based on the precise levelings and triangulations carried on by the Military Survey.)

The closed curve covering the central and greater portion of Sakura-jima marks the boundary of the elevation area.

The other curves are the depression lines of 2 and 1 metres.



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57. Triangulation: horizontal displacement. The triangulation surveys in 1898 and in 1914 (see § 58) also revealed remarkable effects of the recent eruption in the production of the considerable horizontal displacements of the different trigonometrical points in Sakura-jima and along the coast of Kagoshima Bay. As will be observed from Table XXXVI and the map (fig. 44), the displacements at the three places of Atago-yama, Gohonmatsu, and Hatane, in the S.W. part of Sakura-jima, were 2.04 to 3.62 m, and directed towards the south or S. slightly W. On the contrary, at the three places of Hakamagoshi, Isodaira, and Kamano, at the W. and N. parts of the island, the displacements, which varied from 1.08 to 4.52 m (absolute maximum), were directed toward the N. approximately or toward the N.E. Thus the N. and S. portions of Sakura-jima have after the recent eruption been displaced outwards in contrary directions, and it appears that the disturbance, whether horizontal or vertical, probably attained the maximum intensity along an axis AA situated between the two series of stations at distances reciprocally proportional to the amount of the displacement at the latter. This zone, so far as is indicated in the map, practically coincides with the western half of the "fissure line" of the present eruption (the line II II, in fig. 2), suggesting the following process in the topographical change: (i), previous to the eruption, the upheaval was most marked along the zone AA and its eastern prolongation, the different points on the N. and S. portions of the island being pulled inwards or centrally; (ii), at the outbreak, causing the formation of several craterlets and "eruptive cracks," the stress along the zone AA was partially relieved, and the different places on both sides of the latter rebounded back outwards; and, (iii), the subsequent partial settling down of the mountain mass, and the formation of the principal centre of maximum depression to the N., and of a secondary centre to the S.W., of Sakura-jima, have augmented the above-supposed outward motion and resulted in the formation of the horizontal displacement in question.

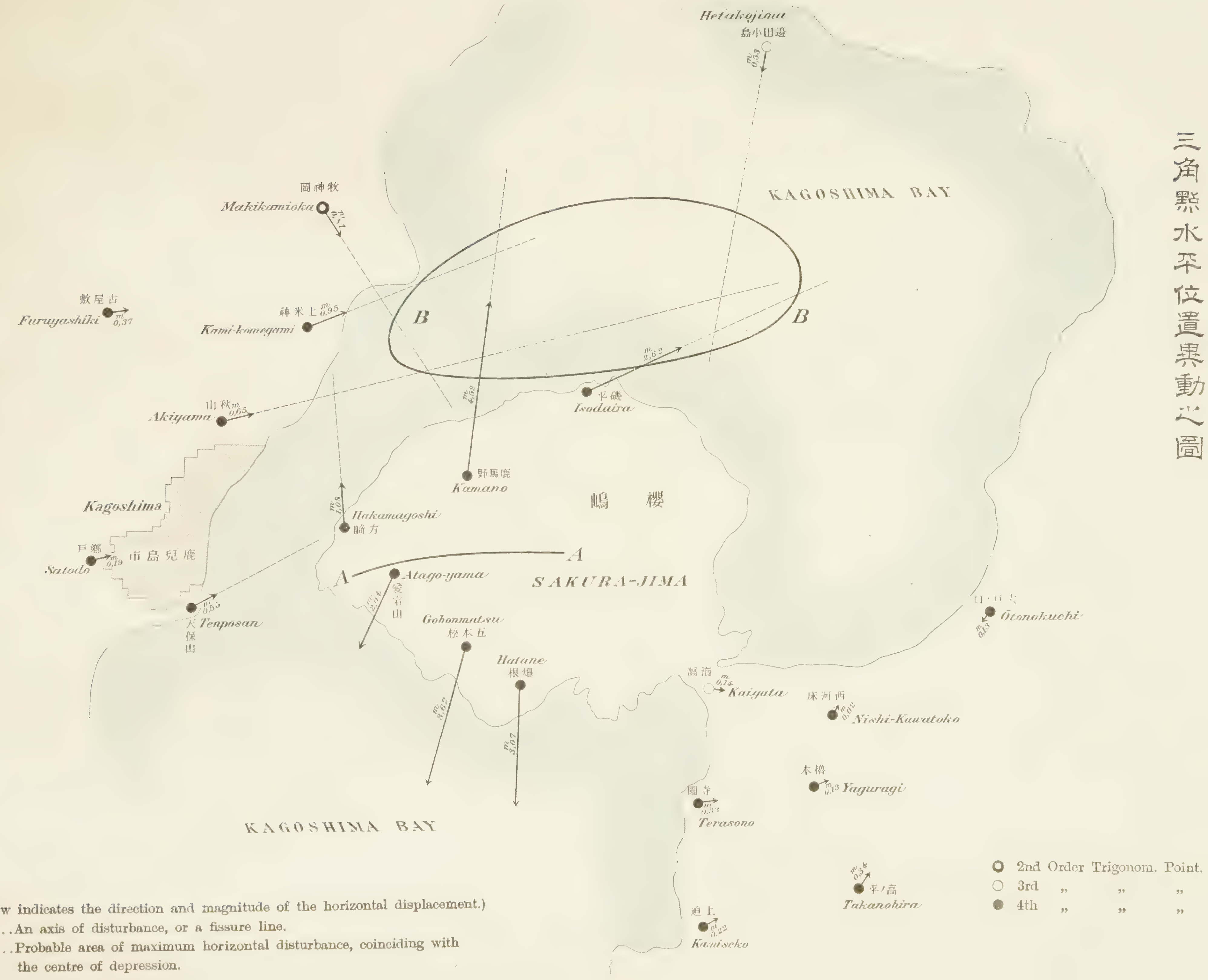
Along the coast of Ōsumi, to the S.E. of Sakura-jima, the displacement was slight and less than 0.34 m. On the other hand, the displacements at different places along the N.W. coast of the bay, from Kagoshima to Kajiki, were much larger, varying from 0.53 to 0.95 m. These, as well as the large displacements at the W. and N. parts of Sakura-jima, converge more or less toward an elliptical area BB, which may be taken as roughly indicating the area of the greatest depression. A secondary area of depression seems to exist to the S.W. of Sakura-jima. The position of the area BB is fairly in harmony with fig. 42, which indicates the results deduced from the precise levelings.

To sum up:—Sakura-jima and the neighbouring districts underwent after the eruption a general depression from the upheaved level attained before the outburst, in such a way that the inner area of the island did not fully regain its original height, but retained a certain amount of the elevation (when compared to the state in 1898), separating the two centres of depression on the N. and S. sides.

58. Triangulation: height difference. The alterations in height in Sakura-jima itself, where there is no bench-mark net, can not be ascertained by the method of precise leveling. Much light has, however, been thrown on the vertical as well as horizontal displacements in the principal area concerned from the measurements carried on by the Military Survey in Oct.–Dec., 1914, which relates to the 1, 15, 21, and 1 trigonometrical points respectively of the 1st, 2nd, 3rd, and 4th orders, in the island of Sakura-jima and the neighbouring coast districts. The height differences between the new determina-

Fig. 44. Map showing the Results of the Triangulations carried on by the Military Survey: Horizontal Displacements of the different Trigonometrical Points in and about Sakura-jima, due to the Eruption of 1914.

三角點水平位置異動之圖



(Arrow indicates the direction and magnitude of the horizontal displacement.)

AA.... An axis of disturbance, or a fissure line.

BB.... Probable area of maximum horizontal disturbance, coinciding with the centre of depression.

tions and the old ones, made in 1898, are given in Table XXXIX.

Amongst the others, the height differences suffered by the 7 third-order trigonometrical points in Sakura-jima are as follows.

TABLE XXXVI HEIGHT CHANGE AND HORIZONTAL DISPLACEMENT OF TRIGONOMETRICAL POINTS IN SAKURA-JIMA DUE TO THE ERUPTION OF 1914.

Trigonometrical Point.		Locality.	Height		Height * Difference.	Horizontal Displacement. (Amount, and Direction.)	
			in 1898.	in 1914.			
			metre.	metre.	metre.	metre.	
Hakamagoshi	(袴 腰)	Hakamagoshi.	71.97	71.65	−0.32	1.08	N6°W
Atago-Yama	(愛宕山)	W. part of Island.	167.05	166.16	−0.89	2.04	S23°W
Gohonmatsu	(五本松)	S.W. part of Island, near Yuno	230.83	230.03	−0.80	3.62	S14°W
Hatane	(畑 根)	S. part of Island, near Furusato	167.76	166.95	−0.81	3.07	SW
Isodaira	(磯 平)	N. coast of Island, near Shirahama	51.48	49.77	−1.71	2.62	N65°E
Sono-Yama	(園 山)	N.E. part of Island, near Ōmoe-zaki	78.90	77.40	−1.50	—	—
Kamano	(鹿馬野)	N.W. part of Island.	374.24	374.38	+0.14	4.52	N6°E

(*) −, when depressed; +, when elevated.

All of the trigonometrical points (stone marks) in question were not injured by the volcanic eruption, but found intact under cover of pumice and ash, whose thickness reached the maximum amount of 1.4 m at Kamano. The trigonometrical points on the summits of the Minami-dake and Kita-dake were unfortunately destroyed during the outburst, their sites having been broken off by the strong earthquake shocks.

The topographical surveys have also brought to light marked height differences of some hill tops and capes in Sakura-jima and several neighbouring islets, as indicated in Table XXXIX.

According to Table XXXVII, the Oko-jima station (5), is a new 3rd class trigonometrical point set up close to the old one destroyed

TABLE XXXVII. HEIGHT CHANGE OF SUBORDINATE SURVEY STATIONS IN SAKURA-JIMA BEFORE AND AFTER THE ERUPTION of 1914.

Locality.*	Height		Height Difference.
	in 1898.	in 1914.	
	metre.	*metre.*	*metre.*
(1) Top of Hikinohira (引之平)	553	562.7	+ 9.7 ‡
(2) „ „ Gongen-Yama, near Nabe-yama.‡	340	350.4	+10.4 ‡
(3) Top of Nakano-shima (中ノ島).	6.6	3.9	− 2.7
(4) „ „ Moe-jima (燃島).	44	43.2	− 0.8
(5) Flat top of Oko-jima, off the S.W. coast of Island.	40.2	38.7	− 1.5
(6) Moe-zaki promontory, S.W. part of Island.	19	17.1	− 1.9
(7) Kwannon-zaki promontory, S.W. part of Island.	79	76.8	− 2.2

* (3) and (5) are new trigonometrical points whose sites are slightly different from the former ones. ‡ Including the accumulation of pumice and ash. See the text.

by accident some time previously. As the site, however, is the flat top of the islet,⁽¹⁾ the height difference between the two points must be slight, and the discrepancy of 1.5 metres between the new and old height measurements may be regarded as approximately representing the amount of the depression of the ground. Again, the position of the new Nakano-shima station (3), is slightly different from the former one, but like the latter refers to the highest point in the islet; the difference of 2.7 m between the old and new heights may therefore denote also the approximate amount of the depression. The stations of Moe-jima (4), Moe-zaki (6), and Kwannon-zaki (7), are not trigonometrical points, but are the highest sites in the localities concerned, where the precipitation of ashes on the occasion of the recent eruption was from a few inches up to about 1 foot; the amounts of the depression at these three places are consequently to be regarded as being roughly accurate.

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(1) Used as a battery ground by Prince Shimazu, *daimyo* of Satsuma, in the engagement with the British fleet in 1863.

The measurements on the Hikinohira (1) and Gongen-yama (2), which relate also not to trigonometrical points, but to the summits of the respective hills, indicate each an apparent height *increase* of about 10 metres. For these stations, sufficiently near to the craterlets, it is of course necessary to take into consideration the amount of the precipitation of ash and pumice. Now, on the N. flank of Nabe-yama and at the base of Gongen-yama opposite the latter, the accumulation of the volcanic ejecta, chiefly pumice, was about 3 metres in thickness, being probably greater than that on the top of Gongen-yama itself, which stands northwards and a little out of the way of the main course of the zone of ash-precipitation. Making a due allowance in this connection, the summit of the last-named hill seems to have been elevated at least some 7½ metres. As regards Hikinohira, it is true that the hill is quite near to No. 1 craterlet on the W., or Yoko-yama, side. But the total amount of the ash and pumice emitted from the craterlets on this side must be much smaller than that given out from the craterlets on the E. or Nabe-yama, side, and I am inclined to believe the accumulation on the top of Hikinohira to be a few metres. From this it follows that the hill in question must have been elevated also at least a few metres.

The errors in the height measurements of the trigonometrical points given in Table XXXVI are believed to be less than 0.1 metre. Those in the topographical measurements given in Table XXXVII may be much larger, but probably under 1 metre. On the whole, the results contained in these two tables are mutually consistent. Thus the depression in the N. and N.E. parts of Sakura-jima are 1.50 to 1.71 metres, while that of the Anei islets of Moe-jima and Nakano-shima are 0.8 to 2.7 metres. Again, the depression at the S. and W. parts of the island was about 0.8 or

0.9 metre, while that of the two S.W. promontories and of Oko-jima off these latter was from about 1.5 to 2.2 metres.

That the districts about the new craterlets, more especially the tops of the side cones or domes like Hikinohira and Gongen-yama, should suffer an upheaval in consequence of the powerful eruption is probable enough, as noted in § 57. The trigonometrical point on the top of Kamano-yama, 374 m in height, in the N.W. part of the island, also indicates a slight upheaval of 0.14 m. As is illustrated in fig. 43, in which the curves have been drawn by interpolations, there lies a submarine area of the depression greater than 2 metres to the N. of Sakura-jima, while the depression lines of 1 and 2 metres cover the S.W. corner of the island and the adjacent sea-bottom portion. The line, along which neither upheaval nor depression took place, is an oval, 7½ km in diameter which runs at an average distance of about 1½ km from and inside the coast, except at the S.E. part where it touches the latter. Inside and along this curve of no height change, which includes Nabe-yama and Gongen-yama on the east, and Hikinohira, the 400-metre hill (above Akobaru), and Kamano-yama on the west, the ground seems to have been more or less upheaved, representing the residual effect of the elevation, whose amount had probably been much greater just before the volcanic outburst and maximum at the immediate neighbourhoods of the new craterlets. On the other hand, there is no positive fact indicating an elevation of the central peaks or main old craters.

59. Well-water at Futamata. In connection with the phenomenon of the depression of the ground is of interest the difference which came to exist in the level of water of four wells in the village of Futamata at the N. coast of Sakura-jima, situated about 70 metres from the beach and about 7 metres in depth. Before the eruption, the wells used to be dried at low tide times, while since 1915 there is water to a depth of 5 or 6 feet even on such occasions. Again, the wells at the village of Saido have still their water level some 5 feet higher than that before the eruption. It is probable that these wells have a communication with the neighbouring sea, the apparent elevation of their water level being in reality the effect of the depression of the ground.

60. Comparison of eruption of Sakura-jima with that of Usu. On the occasion of the Usu eruption in 1910, nearly 50 craterlets were formed on the northern flank, the outbursts consisting in the explosive emission of ash and rock fragments, attended by no exposure or outflow of red hot lava. The eruption was accompanied by remarkable disturbances of the ground, which not only produced a new mountain elevated to the height of 600 feet above the level of the adjacent Lake Toya, but also affected the whole district about the volcano, causing a rise of 0.36 m even at the coast of Volcano Bay.* It is likely that the mountain mass including the two old domes of Ō-Usu and Ko-Usu also acquired some height increase: in fact, the level change was mainly a phenomenon of upheaval. In the Sakura-jima eruption of 1914, there were formed a great number of craterlets, whence issued a vast quantity of ash, pumice, and molten lava; followed, at the cessation of the active outbursts, by a general depression of the ground of Sakura-jima and adjacent districts, to the maximum amount of at least 1.7 m at the northern part of the island and of 1 m or more at the N. W. coast of Kagoshima Bay (§ 58). The opposite manifestations of level change in the Usu and Sakura-jima eruptions, which are by no means incompatible to each other, are to be regarded as expressing the two principal successive phases in the process of an energetic outburst from a small volcano. Thus, in the case of Usu the elevation was probably the result of an application of an upward pressure from below in consequence of the volcanic effort to force up the magma. The long accumulated volcanic force of Sakura-jima, however, had probably been causing, for several decades of years, a continued upheaval of the neighbouring districts (§ 49), until the outflow of lava in the great eruption of 1914 created a sort of vacant space below the latter and induced the settlement of the ground. Both Usu and Sakura-jima, which are very small in volume and height, are powerful in volcanic efforts; this being the reason of the occurrence of the remarkable elevation or depression accompanying their outbursts.

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* See the Bulletin Vol. V, Nos. 1 and 3.

TABLE XXXVIII. HEIGHT CHANGE OF BENCH-MARKS BETWEEN JULY-AUG., 1914 AND FEB. 1915.

* *Minus*, when depressed; *plus*, when elevated.

Bench-Mark.					Height in		Difference.*
Locality.				No.	July–Aug., 1914.	Feb., 1915.	
[Aira County, Province of Ōsumi]					metre	metre	metre
Fukuyama.	福山村	福山	鳥越	2793	380.744	380.744	±0.000
”	”	”	野平	2794	337.010	337.008	−0.002
”	”	”	舊城平	2795	254.205	254.195	−0.010
”	”	”	中ノ平	2796	164.267	164.249	−0.018
Shikine.	敷根村	麓	垂水	2797	88.223	88.205	−0.018
”	”	”	宇都	2488	56.847	56.826	−0.021
”	”	”	節句田	2487	3.002	2.974	−0.028
Hi. Kokbu.	東國分村	湊	竿富	2486	2.624	2.585	−0.039
”	”	小	西山	2485	4.862	4.813	−0.049
Ni. Kokbu.	西國分村	住吉		2484	2.939	2.890	−0.049
”	”	野久美田		2483	11.610	11.561	−0.049
”	”	小濱		2482	15.434	15.386	−0.048
Kajiki.	加治木町	日木山	龍口	2481	46.258	46.220	−0.038

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Pl. XXXII.

鹿兒島灣附近鐵道線路地變之圖

吉松停車場ヨリ鹿兒島停車場ニ至ル

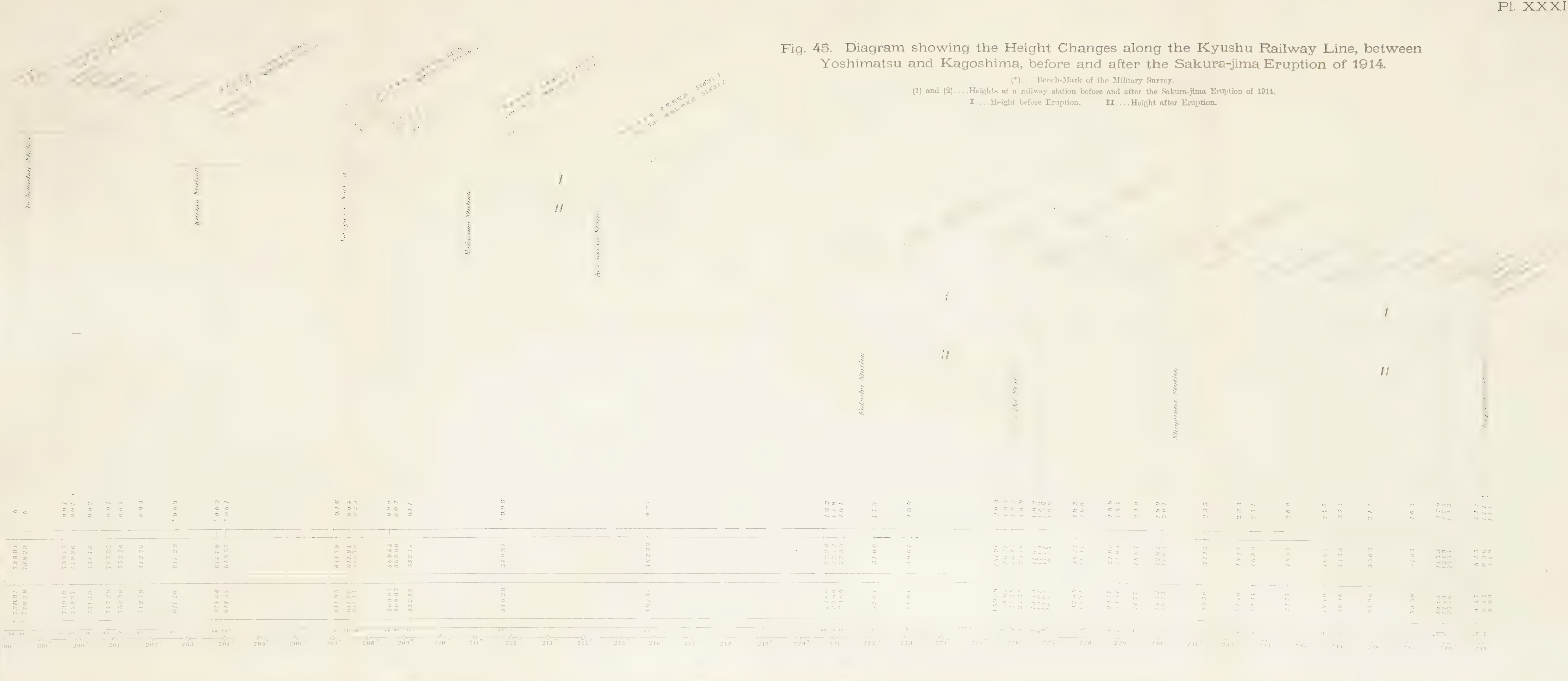

Fig. 45. Diagram showing the Height Changes along the Kyushu Railway Line, between Yoshimatsu and Kagoshima, before and after the Sakura-jima Eruption of 1914.

(*)....Bench-Mark of the Military Survey.
(1) and (2)....Heights at a railway station before and after the Sakura-jima Eruption of 1914.
I....Height before Eruption. II....Height after Eruption.

TABLE XXXVIII. *(Cont.)*

Bench-Mark.		Height in		Difference.
Locality.	No.	July-Aug., 1914.	Feb., 1915.	
		metre	metre	metre
Kajiki. 加治木町 木田 向江町	2480	2.644	2.612	−0.032
" " " 別府川	2479	9.361	9.329	−0.032
Chōsa. 帖佐村 東餅田	2478	9.694	9.661	−0.033
Shigetomi. 重富村 脇元 渡瀬	2477	4.586	4.549	−0.037
" " " 尾崎	2476	11.441	11.401	−0.040
[Kagoshima County, Province of Satsuma]				
Yoshino. 吉野村 吉野 水ヶ谷	2475	5.244	5.201	−0.043
" " " 吉野	2474	6.198	6.143	−0.055
" " " "	2473	5.180	5.135	−0.045
" " " "	2472	11.027	10.984	−0.043
" " " "	2471	9.807	9.780	−0.027
" " " "	2470	7.525	7.512	−0.013
[Kagoshima City]				
Ogawa-machi. 小川町	2469	2.340	2.336	−0.004
Hirano-machi. 平野町	2468	4.360	4.370	+0.010

TABLE XXXIX. HEIGHTS OF TRIGONOMETRICAL POINTS OF 2ND, 3RD, AND 4TH ORDERS IN SAKURA-JIMA AND VICINITY, BEFORE AND AFTER THE ERUPTION OF 1914.

‡ *Minus*, when depressed; *plus*, when elevated.

* Trigonometrical Point set up at a new site near the old one destroyed by the eruption.

Trigonometrical Point.		Height in		Difference.‡
Order.	Locality.	1898.	1914.	
	[Sakura-jima and Neighbouring Islets.]	metre	metre	metre
III	Hakamagoshi. 袴腰 (城山)	71.97	71.65	−0.32
"	Atago-yama. 愛宕山	167.05	166.16	−0.89
IV	Islet of Kanze. 神瀬	7.10	2.89	*
II	Oko-jima (Off Moe-zaki). 沖小島 (燃崎附近)	40.17	38.65	*
"	Heta-Kojima. 邊田小島	124.33	123.27	−1.07

TABLE XXXIX. (*Cont.*)

Trigonometrical Point.		Height in		Difference.
Order.	Locality.	1898.	1914.	
		metre	metre	metre
II	Nakano-Shima. 中之島	6.59	3.94	*
III	Isodaira (near Shirahama). 磯平(白濱附近)	51.48	49.77	−1.71
,,	Take-yama (Maruzuka, near Komen). 竹山 (丸塚)	78.87	77.38	*
,,	Kamano (above Fujino). 鹿馬野 (藤野附近)	374.24	374.38 375.34	+0.14
II	Kita-dake (Mitake), or N. Peak. 御岳	1132.69	1110.23	*
III	Minami-dake, or S. Peak. 南岳	1069.58	1059.75	*
,,	Inuzuka-yama (Yobinotsuka). 黒髮, 呼之塚, 犬塚山	328.42	122.28	*
,,	Gohonmatsu (near Yuno). 湯之, 字五本松	230.83	230.03	−0.80
,,	Hatane (near Furusato). 古里, 畑根	167.76	166.95	−0.81
	[Kimotsuki County, Province of Ōsumi.]			
II	Sakkabira (Hayasaki). 海潟, 字早崎	325.49	324.77	−0.72
III	Nishi-Kawatoko (near Fumoto). 牛根麓, 字ヤシキノ原	297.33	296.89	−0.44
,,	Yaguragi (near Kaigata). 海潟, 字櫓木	568.06	567.77	−0.29
,,	Terasono (near Kaigata). 海潟, 字寺園	95.60	95.29	−0.31
,,	Takanohira (Ichiki). 大字市木, 字高ノ平	574.80	574.53	−0.27
,,	Kamiseko (Ichiki). 同上, 字上迫	83.90	83.76	−0.14
II	Takaki (Ichiki). 大字高城, 字平松	123.40	123.18	−0.22
III	Ōtonokuchi (Ushine). 牛根, 大字麓, 大戸ノ口	319.82	349.43	−0.39
II	Bisago-dake (Ushine). 鵜岳, 字三方崩	885.25	884.98	−0.27
	[Aira County, Province of Ōsumi.]			
II	Kawara (Shimizu-mura). 姶良郡清水村, 大字川原	229.38	229.23	−0.15
,,	Sojinno-oka (Fukuyama). 福山, 字惣陣平	483.71	483.43	−0.28
,,	Fukuchi (Fukuyama). 同上, 字福地	563.49	563.17	−0.32
,,	Neko-dake (Kajiki). 加治木町, 字猫嶽	189.59	189.04	−0.55
	[Kagoshima County, Province of Satsuma.]			
III	Gōto (Take). 西武田村, 大字武, 字郷戸	123.35	123.05	−0.30
,,	Tempōzan (Kagoshima). 鹿兒島市, 天保山	4.44	4.09	−0.35
,,	Naka-Ōtsuka. 鹿兒島郡中郡宇村, 大字中, 字中大塚	104.15	103.87	−0.28
II	Tagami (near Takeda). 西武田村, 大字田上	126.25	126.11	−0.14
,,	Inuseko (Ishiki-mura). 伊敷村, 大字犬迫	190.25	189.92	−0.33
,,	Motona (Yoshida-mura). 吉田村, 大字本名	486.50	——	——
I	Hirakamioka (Yoshida-mura). 大字宮ノ浦, 字底内	552.52	551.64	−0.88

TABLE XXXIX. (*Cont.*)

Trigonometrical Point.		Height in		Difference.
Order.	Locality.	1898.	1914.	
		metre	metre	metre
III	Furuyashiki (Yoshino-mura). 吉野村,大字岡ノ原,字古屋敷	162.40	161.96 161.29	−0.44
„	Kami-Komegami (Yoshino-mura). 大字吉野, 上米神	273.68	272.89	−0.79
„	Akiyama (Yoshino-mura). 同 上, 字瀧ノ神平	145.41	144.91 (1) 143.48 (2)	−0.50 *
II	Sakamoto (Yoshino-mura). 同 上, 字坂元	160.87	159.98	*

(1) Before the re-setting; (2) after the re-setting.

TABLE XL. HEIGHTS OF BENCH-MARKS BEFORE AND AFTER THE ERUPTION OF 1914.

(The difference is *minus*, when depressed, and *plus*, when elevated.)

* Bench-mark re-set.

Bench-Mark.		Before Eruption.		After Eruption.		Difference.
Locality.	No.	Month, Year.	Height.	Month, Year.	Height.	
[Province of Hyuga.]			metre		metre	metre
Hososhima. 東臼杵郡細島町, 字伊勢町	4	X, 1894	2.526	I, 1915	2.526	0.000
Tomitaka. „ 富高村, 日知屋, 古 田	4.1	„	1.606	„	1.583	−0.023
„ „ „ „ 江 頁	4.2	„	3.692	„	3.690	−0.002
„ „ „ 財光寺, 御堂川	2718	„	6.352	„	6.352	0.000
Iwawaki. „ 岩脇村, 平 岩, 赤 岩	2719	„	3.436	„	3.435	−0.001
„ „ „ „ 宮ノ上	2720	„	18.558	„	18.559	+0.001
„ „ „ „ 石ノ田	2721	„	6.551	„	6.552	+0.001
„ „ „ 幸 脇, 番屋ノ後	2722	„	47.592	„	47.595	+0.003
Mimitsu. 兒湯郡, 美々津町, 高 松, 北石並	2723	„	5.929	„	5.931	+0.002
„ „ „ „ 松ノ本	2724	„	35.763	„	35.766	+0.003
Tsuno. „ 都農村, 川 北, 寺迫北原	2725	„	28.454	„	28.456	+0.002
„ „ „ „ 心見往還	2726	„	21.484	„	21.486	+0.002
„ „ „ „ 境ケ谷	2727	„	36.030	„	36.032	+0.002
„ „ „ „ 都農新町	2728	„	29.844	„	29.841	−0.003
Kawanami. „ 川南村, 川 南, 中猪久保	2729	„	48.811	„	48.799	−0.012
„ „ „ „ 東 原	2730	„	54.841	„	54.838	−0.003

TABLE XL. (*Cont.*)

Bench-Mark.						Before Eruption.		After Eruption.		Difference.
Locality.					No.	Month, Year.	Height.	Month, Year.	Height.	
	[Porvince of Hyuga.]						metre		metre	metre
Kawanami.	兒湯郡,	川南村,	平　田,	野稲尾	2731	X, 1894	52.988	I, 1915	52.987	–0.001
"	"	"	川　南,	仲　原	2732	"	24.761	"	24.761	0.000
Uwae.	"	上江村,	持　田,	番野地	2733	XI, 1894	61.412	"	61.412	0.000
"	"	"	"	計　塚	2734	"	46.500	"	46.488	–0.012
"	"	"	"	小丸出口	2735	"	4.833	"	4.827	–0.006
Takanabe.	"	高鍋町,	南高鍋,	筏	2736	"	4.442	"	4.434	–0.008
"	"	"	"	茂廣毛平	2737	"	10.536	"	10.528	–0.008
"	"	"	"	前牟田	2738	"	11.207	"	11.153	–0.054
Tonda.	"	富田村,	日　置,	六反田	2739	"	10.955	"	10.940	–0.015
"	"	"	上富田,	越馬場	2740	"	5.541	"	5.522	–0.019
"	"	"	下富田,	軍　瀬	2741	"	3.481	"	3.466	–0.015
Hirose.	宮崎郡,	廣瀬村,	下田島,	福　島	2742	"	3.039	"	3.019	–0.020
"	"	"	"	井手牟田	2743	"	11.854	"	11.836	–0.018
Hirose.	"	"	下那珂,	馬場下	2744	"	8.753	"	8.698	–0.055
Sumiyoshi.	"	住吉村,	島ノ内,	成　尾	2745	"	8.077	"	8.046	–0.031
"	"	"	"	内　添	2746	"	12.405	"	12.378	–0.027
"	"	"	芳　士,	蓮ヶ池	2747	"	9.759	"	9.717	–0.042
"	"	大宮村,	花ヶ島,	赤江町	2748	"	7.936	"	7.902	–0.034
Miyazaki.	"	宮崎町,	江平町,	河　骨	2749	"	7.508	"	7.449	–0.059
"	"	"	上別府,	春　田	2750	"	5.462	"	5.436	–0.026
Oyodo.	"	大淀村,	太　田,	南小路	2751.1	"	5.752	XII, 1914	5.704	–0.048
"	"	"	"	堂ノ下	2751	"	7.760	"	7.742	–0.018
"	"	"	大　塚,	宮　田	2752	"	7.216	"	7.200	–0.016
Ikime.	"	生目村,	小　松,	ロノ坪	2753	XII, 1894	8.548	"	8.529	–0.019
"	"	"	柏　原,	高　後	2754	"	22.850	"	22.837	–0.013
"	"	"	富　吉,	山　下	2755	"	13.509	"	13.492	–0.017
Takaoka.	東諸縣郡,	高岡村,	花　見,	竹ノ内	2756	"	16.539	"	16.508	–0.031
"	"	"	"	粟　野	2757	"	16.260	"	16.244	–0.016
"	"	"	五　町,	顯本瀬	2758	"	14.263	"	14.246	–0.017
"	"	"	浦ノ名,	河原田	2759	"	19.924	"	20.119	*
"	"	"	"	赤　谷	2760	"	19.365	"	19.600	*

TABLE XL. *(Cont.)*

Bench-Mark.						Before Eruption.		After Eruption.		Difference.
Locality.					No.	Month, Year.	Height.	Month, Year.	Height.	
	[Province of Hyuga.]						metre		metre	metre
Takaoka.	東諸縣郡,	高岡村,	浦ノ名,	早面流	2761	XII, 1894	25.416	XII, 1914	26.101	*
,,	,,	,,	,,	宇　都	2762	,,	35.530	I, 1915	35.788	*
,,	,,	,,	,,	小　峰	2763	,,	31.254	,,	31.233	−0.021
,,	,,	,,	內　山,	去　川	2764	,,	43.504	,,	43.444	−0.060
Takajo.	北諸縣郡,	高城村,	四家村,	本八重	2765	,,	113.321	,,	113.304	−0.017
Takaoka.	東諸縣郡,	高岡村,	內　山,	和　石	2766	,,	204.646	,,	204.630	−0.016
Takajo.	北諸縣郡,	高城村,	四家村,	樣ヶ野	2767	,,	147.595	,,	147.583	−0.012
,,	,,	,,	,,	蓑　野	2768	,,	153.877	,,	153.858	−0.019
,,	,,	,,	,,	,,	2769	,,	170.432	,,	170.349	−0.083
,,	,,	,,	有水村,	大　丸	2770	,,	196.857	,,	196.846	−0.011
,,	,,	,,	,,	市ノ野	2771	,,	175.994	,,	175.975	−0.019
,,	,,	,,	,,	松　元	2772	,,	143.349	,,	143.322	−0.027
,,	,,	,,	石山村,	鳥井原	2773	,,	131.178	,,	131.128	−0.050
,,	,,	,,	,,	石龜岩	2774	,,	128.652	,,	128.616	−0,036
,,	,,	,,	穗滿坊村,	和　田	2775	,,	144.201	,,	144.168	−0.033
,,	,,	,,	櫻木村,	弓細工	2776	,,	140.024	,,	140.000	−0.024
Okimizu.	,,	沖水村,	高木村,	出　口	2777	,,	136.417	,,	136.395	−0.022
,,	,,	,,	,,	大圓松	2778	,,	141.961	XII, 1914	141.931	−0.030
,,	,,	,,	川東村,	三本松	2779	,,	142.631	,,	142.601	−0.030
,,	,,	,,	,,	松　原	2780	,,	144.765	,,	144.734	−0.031
Miyakonojo.	,,	都城町,	中　町,	中　町	2781	I, 1895	143.905	,,	143.870	−0.035
Isoichi.	,,	五十市村,	五十町,	瀨戸ノ上	2782	II, 1911	143.171	,,	143.146	−0.025
,,	,,	,,	,,	油　田	2783	I, 1895	150.964	,,	150.938	−0.026
	[Province of Ōsumi.]									
Sueyoshi.	囎唹郡,	末吉村,	深　川,	中崎道	2784	,,	192.311	,,	192.280	−0.031
,,	,,	,,	,,	堂薗野久尾	2785	,,	231.472	,,	231.430	−0.042
,,	,,	,,	,,	東坂ノ上	2786	,,	241.916	,,	241.873	−0.043
,,	,,	,,	,,	阿ッ田	2787	,,	274.615	,,	274.552	−0.063
,,	,,	,,	,,	舊驛所	2788	,,	292.737	,,	292.665	−0.072
,,	,,	,,	諏訪方,	大角豆ヶ迫	2789	,,	292.235	,,	292.146	−0.089
Fukuyama.	姶良郡,	福山村,	佳例川,	柴　健	2790	,,	297.909	,,	297.794	−0.115

TABLE XL. *(Cont.)*

Bench-Mark.		Before Eruption.		After Eruption.		Difference.
Locality.	No.	Month, Year.	Height.	Month, Year.	Height.	
[Province of Ōsumi.]			metre		metre	metre
Tsuneyoshi. 囎唹郡, 恒吉村, 坂 本, 鳩ヶ山	2791	I, 1895	308.005	XII, 1914	307.862	−0.143
Fukuyama. 始良郡. 福山村, 佳例川, 花建原	2792	,,	367.470	,,	367.315	−0.155
,, ,, ,, 福 山, 鳥 越	2793	,,	380.950	,,	380.744	−0.206
,, ,, ,, ,, 野 平	2794	,,	337.254	VIII,1914	337.010	−0.244
,, ,, ,, ,, 葛城平	2795	,,	254.465	,,	254.205	−0.260
,, ,, ,, ,, 中ノ平	2796	,,	164.605	,,	164.267	−0.338
Shikine. ,, 敷根村, 麓, 垂 水	2797	,,	88.592	,,	88.223	−0.369
,, ,, ,, ,, 宇 都	2488	II, 1892	57.274	,,	56.847	−0.427
,, ,, ,, ,, 節句田	2487	,,	3.487	,,	3.002	−0.485
Higashi Kokbu. ,, 東國分村; 湊, 竿 富	2486	IV, 1892	3.240	,,	2.624	−0.616
,, ,, ,, 小, 西 山	2485	,,	5.547	,,	4.862	−0.685
Nishi Kokbu. ,, 西國分村, 住 吉, ——	2484	,,	3.620	,,	2.939	−0.681
,, ,, ,, 野久美田, ——	2483	,,	12.300	VII, 1914	11.610	−0.690
,, ,, ,, 小 濱, ——	2482	III, 1900	16.118	,,	15.434	−0.684
Kajiki. ,, 加治木町, 日木山, 龍 口	2481	,,	46.835	,,	46.258	−0.577
,, ,, ,, 木 田, 向江町	2480	,,	3.204	,,	2.644	−0.560
,, ,, ,, ,, 別府川	2479	,,	9.897	,,	9.361	−0.536
Chōsa. ,, 帖佐村, —— 東餅田	2478	,,	10.220	,,	9.694	−0.526
Shigetomi. ,, 重富村, 脇 元, 渡 瀬	2477	,,	5.194	,,	4.586	−0.608
,, ,, ,, ,, 尾 崎	2476	,,	12.144	,,	11.441	−0.703
[Province of Satsuma.]						
Yoshino. 鹿兒島郡, 吉野村, 吉 野, 水ヶ谷	2475	,,	6.020	,,	5.244	−0.776
,, ,, ,, ,, ,,	2474	,,	7.092	,,	6.198	−0.894
,, ,, ,, ,, ,,	2473	IV, 1892	5.950	,,	5.180	−0.770
,, ,, ,, ,, ,,	2472	,,	11.685	VI, 1914	11.027	−0.658
,, ,, ,, ,, ,,	2471	,,	10.334	,,	9.807	−0.527
,, ,, ,, ,, ,,	2470	,,	7.971	,,	7.525	−0.446
Ogawa-machi. 鹿兒島市, 小川町, —— ——	2469	II, 1892	2.747	,,	2.340	−0.407
Hirano-machi. ,, 平野町, —— ——	2468	,,	4.598	,,	4.360	*
Sonta-machi. ,, 草牟田町, —— ——	2467	,,	7.449	,,	7.395	*
Ishiki. 鹿兒嶋郡, 伊敷町, 上伊敷, 脇園ノ迫	2466	IV, 1892	14.219	,,	13.917	−0.302

TABLE XL. (*Cont.*)

Bench-Mark.						Before Eruption.		After Eruption.		Difference.
Locality.					No.	Month, Year.	Height.	Month, Year.	Height.	
[Province of Satsuma.]							metre		metre	metre
Ishiki.	鹿兒嶋郡,	伊敷町,	上伊敷,	野稻ヶ原	2465	IV, 1892	17.888	VI, 1914	17.597	−0.291
,,	,,	,,	小山田,	鬬ノ平	2464	,,	26.805	,,	26.514	−0.291
,,	,,	,,	,,	アブミ坂	2463	,,	66.070	,,	65.811	−0.259
,,	,,	,,	,,	內　門	2462	,,	105.638	,,	105.413	−0.225
,,	,,	,,	,,	ヤケ山	2461	,,	143.587	,,	143.337	−0.250
Shimo-Ijuin.	日置郡,	下伊集院町,	麥生田,	笹　原	2460	II, 1892	101.299	,,	101.128	−0.171
,,	,,	,,	下神殿,	永　山	2459	,,	104.868	,,	104.683	−0.185
,,	,,	,,	,,	樋ノ原	2458	,,	82.074	,,	81.893	−0.181
,,	,,	,,	野　田,	崩　下	2457	,,	64.514	,,	64.349	−0.165
,,	,,	,,	苗代川,	樋　掛	2456	,,	55.996	II, 1915	55.870	−0.126
Higashi-Ichiku.	,,	東市來村,	長　里,	古　川	2455	,,	30.053	,,	29.903	−0.150
,,	,,	,,	湯　田,	溝　下	2454	,,	31.625	,,	31.504	−0.121
Nishi-Ichiku.	,,	西市來村,	大　里,	上池田	2453	,,	6.636	,,	6.516	−0.120
,,	,,	,,	,,	西　村	2452	,,	4.560	III, 1915	4.476	−0.084
,,	,,	,,	湊　町,	市口町	2451	,,	2.721	,,	2.616	−0.105
Kushikino.	,,	串木野村,	下　名,	西前床	2450	,,	13.135	,,	13.053	−0.082
,,	,,	,,	,,	コブ下	2449	,,	5.828	,,	5.734	−0.094
,,	,,	,,	下　名,	野下口	2448	,,	38.108	,,	38.020	−0.088
,,	,,	,,	,,	山神下	2447	I, 1892	75.950	,,	75.847	−0.103
Kumanojo.	薩摩郡,	隈之城村,	西　手,	木　場	2446	,,	35.210	,,	35.105	−0.105
,,	,,	,,	東　手,	仁禮木	2445	,,	13.481	,,	13.385	−0.096
,,	,,	,,	西　手,	後牟田	2444	,,	9.415	,,	9.328	−0.087
,,	,,	,,	向　田,	新　町	2443	II, 1900	5.871	,,	5.775	−0.096
Hi.-Mizuhiki.	,,	東水引村,	宮　內,	城ノ後	2442	I, 1892	5.120	,,	5.001	−0.119
,,	,,	,,	五　代,	小野原	2441	,,	13.946	,,	13.850	−0.096
Nishi-Mizuhiki.	,,	西水引村,	小　倉,	栫,	2440	,,	5.161	,,	5.032	−0.129
,,	,,	,,	草　道,	井手平	2439	,,	4.360	,,	4.246	−0.114
,,	,,	,,	網　津,	五反田	2438	,,	4.064	,,	3.953	−0.111
Takaki.	,,	高城村,	湯　田,	火神山	2437	,,	3.864	,,	3.736	−0.128
,,	,,	,,	西　方,	古野岡	2436	,,	24.828	,,	24.747	−0.081
,,	,,	,,	,,	濱　田	2435	,,	3.897	,,	3.787	−0.110

TABLE XL. (*Cont.*)

Bench-Mark.						Before Eruption.		After Eruption.		Difference.
Locality.					No.	Month, Year.	Height.	Month, Year.	Height.	
[Province of Satsuma.]							metre		metre	metre
Akune.	出水郡,	阿久根村,	大 川,	磯 邊	2434	I, 1892	19.217	III, 1915	19.139	−0.078
,,	,,	,,	,,	鳥井ヶ段	2433	,,	11.280	,,	11.201	−0.079
,,	,,	,,	,,	春 田	2432	,,	15.324	,,	15.248	−0.076
,,	,,	,,	,,	牟田平	2431	,,	6.322	,,	6.212	−0.110
,,	,,	,,	西 目,	高之口	2430	,,	4.818	,,	4.690	−0.128
,,	,,	,,	波 留,	建 石	2429	,,	2.684	,,	2.574	−0.110
,,	,,	,,	赤瀨川,	下ノ田	2428	,,	18.858	,,	18.772	−0.086
,,	,,	,,	,,	大山口	2427	,,	27.688	,,	27.605	−0.083
,,	,,	,,	折 口,	岩 掛	2426	,,	14.959	,,	14.873	−0.086
Noda.	,,	野田村,	下 名,	垣 内	2425	,,	4.664	,,	4.545	−0.119
,,	,,	,,	,,	田ノ神丸	2424	,,	17.036	IV, 1915	16.896	−0.140
Naka-Izumi.	,,	中出水村,	莊,	田ノ神	2423	,,	7.029	,,	6.748	−0.281
Takaono.	,,	高尾野村,	下水流,	アザミ原	2422	,,	5.100	,,	5.002	−0.098
Naka-Izumi.	,,	中出水村,	下知識,	西新藏	2421	,,	4.309	,,	4.203	−0.106
,,	,,	,,	,,	原 園	2420	,,	3.832	,,	3.734	−0.098
,,	,,	,,	下鯖淵,	坪ノ屋敷	2419	,,	7.403	,,	7.337	−0.066
,,	,,	,,	,,	下針原	2418	,,	4.885	,,	4.799	−0.086
,,	,,	,,	,,	鹽 屋	2417	,,	9.525	,,	9.458	−0.067
[Province of Higo.]										
Minamata.	葦北郡,	水俣町,	袋,	一ツ橋	2416	,,	43.105	,,	43.037	−0.068
,,	,,	,,	,,	薄 月	2415	,,	5.720	,,	5.589	−0.131
,,	,,	,,	月 浦,	前 田	2414	,,	14.110	,,	14.017	−0.093
,,	,,	,,	濱,	百 間	2413	,,	1.976	,,	1.897	−0.079
,,	,,	,,	陣 內,	陣 町	2412	XII, 1891	3.999	,,	3.923	−0.076
,,	,,	,,	,,	雲雀田	2411	,,	35.800	V, 1915	32.618	*
,,	,,	,,	小津奈木,	前 田	2410	,,	8.064	IV, 1915	7.952	−0.112
Tsunaki.	,,	津奈木村,	岩 城,	櫻 田	2409	,,	59.828	V, 1915	9.086	*
,,	,,	,,	津奈木,	神 前	2408	,,	21.548	IV, 1915	21.469	−0.079
,,	,,	,,	千 代,	千代原	2407	,,	73.208	V, 1915	73.124	−0.084
Yunoura.	,,	湯浦村,	湯 浦,	斧田迫	2406	,,	160.030	,,	159.955	−0.075
,,	,,	,,	,,	山 川	2405	,,	12.546	IV, 1915	12.477	−0.069

TABLE XL. (*Cont.*)

Bench-Mark.						Before Eruption.		After Eruption.		Difference.
Locality.					No.	Month, Year.	Height.	Month, Year.	Height.	
[Province of Higo.]							metre		metre	metre
Yunoura.	葦北郡,	湯浦村,	湯浦,	湯治	2404	XII, 1891	67.030	IV, 1915	66.948	−0.082
Sashiki.	„	佐敷村,	花岡,	淵ノ本	2403	„	8.540	„	8.469	−0.080
„	„	„	„	宇戸	2865	IX, 1891	7.251	„	7.169	−0.082
[Province of Ōsumi.]										
Shikine.	始良郡,	敷根村,	麓,	垂水	2797	I, 1895	88.592	VIII,1914	88.223	−0.369
Fukuyama.	„	福山村,	福山,	塚田	2489	II, 1892	2.602	„	2.254	−0.348
„	„	„	„	熊ノ谷	2490	„	6.060	„	5.759	−0.301
„	„	„	„	元屋敷	2491	„	2.928	„	2.622	−0.306
Ushine.	肝屬郡,	牛根村,	境,	磯,	2492	„	9.735	„	9.302	−0.433
„	„	„	„	磯口	2493	„	6.672	„	6.246	−0.426
„	„	„	„	境崎	2494	„	14.661	„	14.208	−0.453
„	„	„	二川,	磯口平	2495	„	2.516	„	2.160	−0.356
„	„	„	麓,	圖師	2496	„	8.758	„	8.414	−0.344
„	„	„	„	前田	2497	„	5.820	VII, 1914	5.457	−0.363
„	„	„	„	„	2498	„	4.449	„	4.048	−0.401
„	„	„	„	磯,	2499	„	8.708	„	8.240	−0.468
Tarumizu.	„	垂水村,	海潟,	大谷	2500 (A)	„	4.261	„	12.276	*
„	„	„	„	門ノ口	2501	„	6.443	„	6.064	−0.379
„	„	„	„	天神山	2502	„	3.334	„	3.020	−0.314
„	„	„	中俣,	脇田下	2503	„	3.188	„	2.946	−0.242
„	„	垂水村,	田神,	川崎	2504	„	4.355	„	4.148	−0.207
„	„	„	濱平,	黒瀬	2505	„	3.190	„	3.016	−0.174
„	„	„	柊原,	鬼山	2506	„	5.671	IX, 1914	5.496	−0.175
„	„	„	„	上ノ濱	2507	„	3.936	„	3.785	−0.151
Shinjo.	„	新城村,	新城,	南方	2508	V, 1892	3.781	„	3.637	−0.144
„	„	„	„	口ノ坪	2509	„	4.270	„	4.123	−0.147
„	„	„	„	海馬場	2510	„	7.753	„	7.641	−0.112
Hanaoka.	„	花岡村,	木谷,	糸田	2511	„	17.562	„	17.451	−0.111
„	„	„	„	南迫	2512	„	128.413	„	128.296	−0.117

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THE SAKURA-JIMA ERUPTIONS AND EARTHQUAKES.

III.

[Course of Activity in the Sakura-jima Eruption of 1914.]

By

F. Omori, Sc. D.,
Member of the Imperial Earthquake Investigation Committee.

With Plates XXXIII–LXX.

Chapter I. Craterlets and Lava Sources.

1. Zonal arrangement of eruptive vents. In the Sakura-jima eruption of 1914 numerous openings have been formed on two opposite flanks of the mountain. These are arranged on the whole along a nearly straight zone through the centre of Minami-dake, or the South Peak, extending in an E.S.E. and W.N.W. direction approximately normal to the line of the great volcanic chain, which connects the centre of Sakura-jima with Kirishima on the N.E.N. and Kaimon-dake, Iwo-jima, Suwanose-jima, etc., on the S.W.S. (See fig. 2, Pl. IX, in the preceding Number of the Bulletin.) The eruption zone meets at an angle of about 60° the central ridge of the island running in the N. and S. direction.

The eastern craterlets series, whose horizontal extension is about $2\frac{1}{2}$ km and whose lower half crosses obliquely the southern limb of the U-shaped ridge of Nabe-yama, has been formed within the original height limits of 470 and 140 m above sea-level, the lava having thence streamed down mostly sideways to the S.E. portion of the island. On the western side the craterlets extend over the space of the horizontal length of about 2.6 km within the original height limits of 570 and 65 m above sea-level, whence the lava ran down westwards along the valley between Hikinohira and Atago-yama on the south and the hill group of 120 to 400 m height above the village of Akobaru on the north.

On the eastern side, there have been formed several large and small craterlets, all these being connected by a distinct eruption canal or crack. On the western side, where there remains no evident trace of a similar opening, the highest craterlet is the only large one existing in the well preserved condition, the different vents in the lower levels having probably in a part been filled up by the lava streams which flowed over them.

In fig. 1 is shown the original outline of Sakura-jima in the vertical plane through the centre of Minami-dake and the eruption zone, while in figs. 2 and 3 are given the profiles respectively of the E.S.E. and W.N.W. slopes of Minami-dake, both before and after the eruption, with indications of the positions of the different craterlets.[1]

2. Craterlets on eastern side. The volcanic fissure, or zone of eruptive vents, on the eastern side extends along a slightly zigzag line in a general W.N.W.–E.S.E. direction, including amongst the others 7 well-defined large craterlets 100 m or more in diameter. (See figs. 75, 77, and 88.) I have visited the No. 1 craterlet and the highest epening first at the time of my second trip to Sakura-jima in April 1914, when the No. 2 and other lower craterlets were still in active conditions. A detailed inspection of

---

[1] The profiles have been drawn with reference to the Military Survey maps of Sakura-jima of 1:50.000 published in 1912, and one of 1:25,000 completed after the eruption, in 1915.

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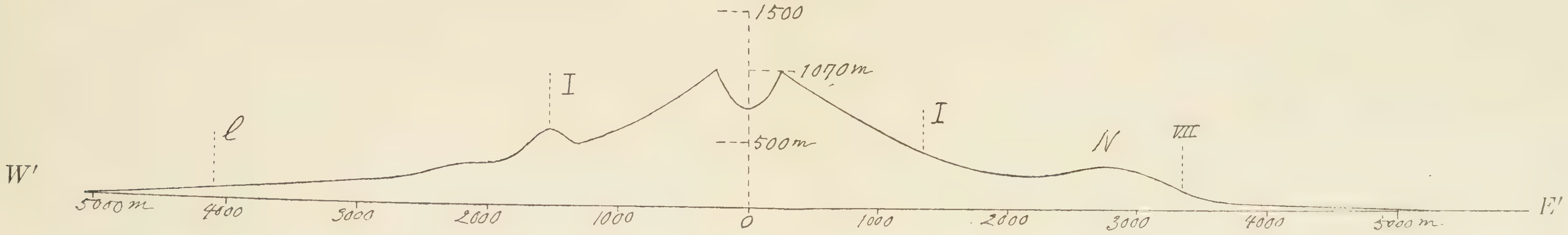
Fig. 1. Sectional Outline of Sakura-jima in the E.S.E. and W.N.W. Direction through Minami-dake, before the Eruption of 1914.

E'......E.S.E. Coast.
W'......W.N.W. side, corresponding to the E. base of Hakamagoshi.
N ......Nabe-yama.
I, VII......Positions of the eastern craterlets Nos. 1 and 7.
I, 1......Positions of the highest and lowest western craterlets.



Figs. 2 and 3. Section of Sakura-jima along the Eruption Fissure through Minami-dake: Diagrams showing the Heights and Successive Mutual Distances of the Craterlets.

Full line gives the contour after, and the dotted line that before, the recent eruption.

Fig. 2.

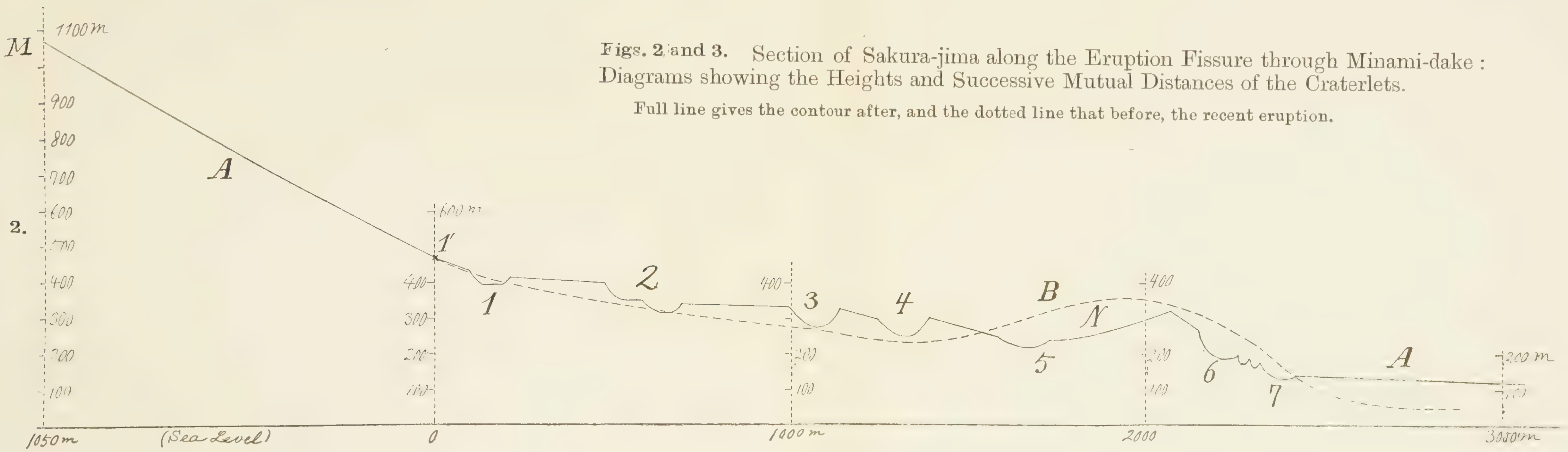
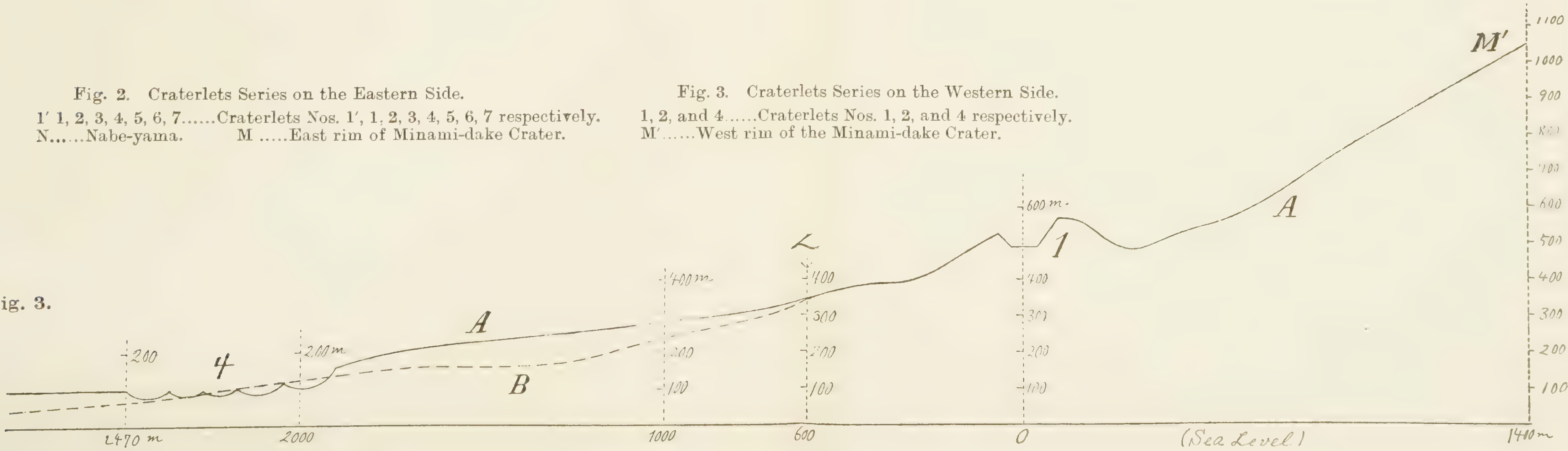


Fig. 2. Craterlets Series on the Eastern Side.
1' 1, 2, 3, 4, 5, 6, 7......Craterlets Nos. 1', 1, 2, 3, 4, 5, 6, 7 respectively.
N......Nabe-yama.
M ......East rim of Minami-dake Crater.

Fig. 3. Craterlets Series on the Western Side.
1, 2, and 4......Craterlets Nos. 1, 2, and 4 respectively.
M'......West rim of the Minami-dake Crater.

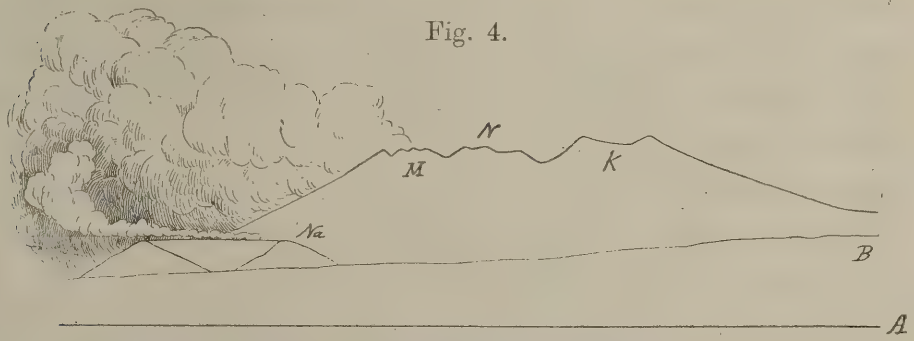
Fig. 3.



the different craterlets along the entire eruption zone was effected later on at the times of my 4th and 5th trips, in April and September, 1915. The craterlets are numbered 1 to 7 in order of descending height.

Highest No. 1′ *vent or "chimney."* The highest vent is a lateral opening, situated at the height of 470 m above sea-level and at the base of a shallow horse-shoe shaped depression on the S.E. flank of Minami-dake. This formed neither an explosive craterlet nor a mouth for lava outflow, but simply a sort of factory chimney, which sent, when seen on Jan. 16th, 1914, white smokes vigorously forward in a slanting down-slope direction over and to the south of Nabe-yama. (See figs. 4 and 76.) The opening whose inner channel might not extend backward horizontally must have been above the surface level of the interior molten lava mass. When again seen in April 1914, the white smokes, whose ejection was no longer strong enough to take place in a straight sidewise course, were given out diffusedly, but in no insignificant amount, from the main original mouth, a hole $1\frac{1}{2}$ m in dimension, with some sulphur deposits, and from a

Fig. 4.



Sakura-jima seen from West: Sketch showing the sidewise ejection of white smokes from the "Chimney," or the highest East side No. 1′ Vent.
K......Kita-dake. N......Naka-dake. M......Minami-dake. Na......Nabe-yama.
A......Sea-level. B......Plateau ground.

number of small sources situated along a fissured zone, about 9 m in width, extending obliquely upwards for the length of about 35 m.

No. 1 *craterlet.* (See fig. 90.) The proper No. 1 or highest craterlet is a conspicuous circular hole of the mouth diameter of 120 m, situated 90 m below the "chimney" at the foot of a horse-shoe slope before noted and on the eastern flank of a sort of a small plateau-like elevation. In April 1914 it has been found to be completely dead and smokeless, the bottom plane, 51 m in diameter, being filled with sand. On the upper or western end, where the rim is highest and is situated 435 m above sea-level, the steep inside wall, 41 m in depth, is made up entirely of hard massive gray lava forming the original rocky layer of the Minami-dake slope, with a covering of the new ejected material. The craterlet in question was essentially explosive in nature and its activity has probably been limited only to a short time interval at the commencement of the eruption, as it had already ceased to make outburst before Jan. 16th, 1914. The lava outflow seems here to have taken place chiefly from a small deep hole at the lower side of, and separated by a single rocky partition from, the No. 1 craterlet, chiefly toward the south.

Eruption canal between No. 1 *and No.* 2 *craterlets.* (See fig. 77.) The lower side of the No. 1 craterlet is continued to the shallow "eruption canal" in an E.S.E. direction pointing toward the S. shoulder of Nabe-yama, throughout which outbursts must have taken place in the earlier stage of the eruption and along which traces of numerous secondary craterlets are remaining. Amongst the others there were two of these latter on the S. side or bank of the canal, which were respectively 35 and 17 m in mouth diameter, both abundantly emitting pungent sulphurous gases even at the end of 1915. For the length of the first 128 m, the canal was about 20 m in depth, and the broad flat bottom, about 100 m in width, was filled with pumice. Thereafter it bifurcates into two narrow branches, of which the northern one is continued for about 130 m till it reaches the head of the No. 2 craterlet. Around the No. 1 craterlet, especially on the higher ground to its S. and S.W., and on the elevated south bank of the canal, there were great many large blocks of lava, 4 metres or more in dimension, evidently thrown out during the active eruptive epoch.

No. 2 compound craterlet. The 2nd large U-shaped craterlet, whose total length is 220 m, and whose upper rim is 400 m above sea-level, is composed of two circular cavities No. 2, A and No. 2, B situated in close proximity, and at different levels such that the bottom of the higher one is continued to the head of the lower. The upper cavity (2, A) whose west side wall is steep and composed of massive gray rocks of the old existence is 50 m deep and 120 m long, while the lower one (2, B) is shallow and is 34 m deep and 100 m long. Unlike the No. 1 craterlet these two cavities continued actively explosive for a long time, so that the bottoms, which were not filled with sand and pumice, as well as the adjacent grounds are covered thickly with blocks of projected lavas, apparently of later date, as these were not coated with ashes. In particular, at the S. brink of the upper cavity (2, A), there was a quite fresh-looking huge bread-crust bomb about 3 m in diameter (fig. 42).

The molten mass given out from the No. 2 craterlet is considerable in amount and covered the higher sloping ground which forms its N. boundary; a portion forced up the W. shoulder of Nabe-yama producing the lava cascade illustrated in fig. 84.

The distance between the lower end of the No. 2 craterlet and the head of the No. 3 craterlet is 300 m.

No. 3 *craterlet.* The 3rd craterlet is quite large and is, unlike the two higher ones, a perfect inverted cone, 60 m in depth, with an almost level circular mouth 150 m in diameter; the upper rim being at the height of 336 m above sea-level. The craterlet wall is made up of lava fragments of reddish colour, and there is no exposure of old native massive rocks. The distance between the lower end of the No. 3 craterlet and the head of the No. 4 craterlet is about 100 m.

No. 4 *craterlet.* (See fig. 91.) The No. 4 craterlet is also a magnificent and nicely cut conical cavity about 150 m in mouth diameter, whose northern margin is at the height of 297 m above sea-level; the depth being about 50 m, and the accurately regular reddish inner side, with exposure of no old rock masses, having a slope angle of 34.° When seen in April 1915, there was at the centre or bottom, an apparently loose heap of lava masses about 20 m in dimension. (See § 9.)

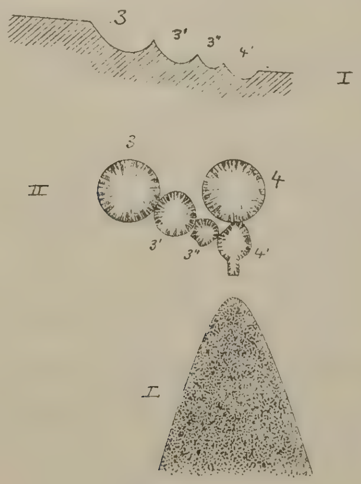


Fig. 5.

Sketch showing the Positions of the Eastern Craterlets Nos. 3, 3,' 3," 4,' and 4.

L......Lava flow.

(I) ......Section through (3) and (4').
(II)......Plan.

Initial Phases of Sakura-jima Eruption. Seen from Tarumizu 11½ km to the S. E. of the Centre of Sakura-jima, on the morning of Jan. 12th, 1914. (R. Higo, photo.)

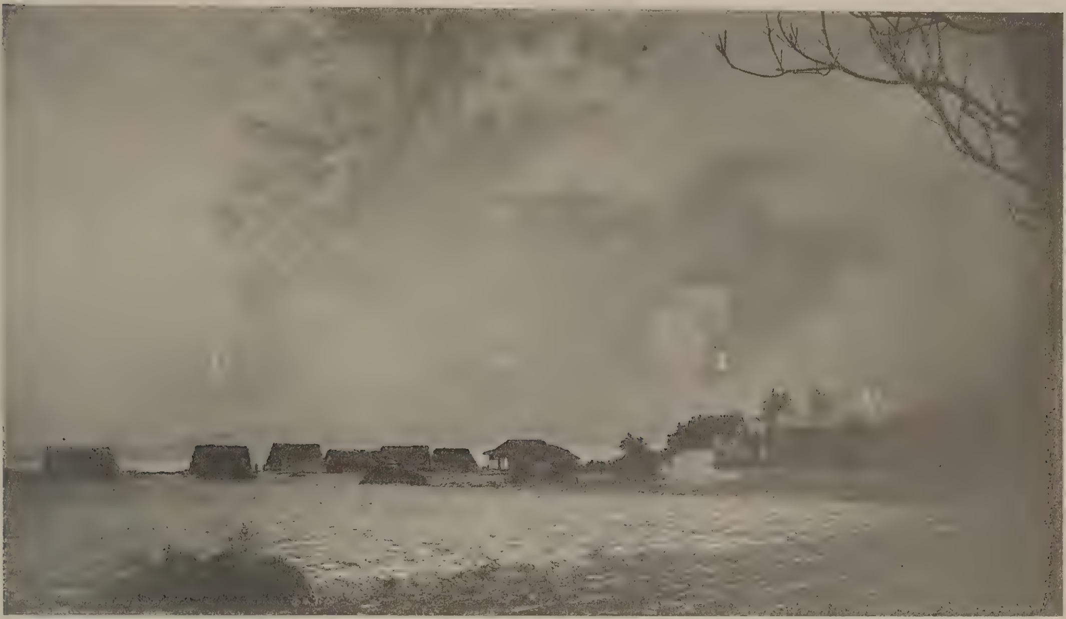


Fig. 6. View taken about 20 min. after the Commencement of the Eruption.

(×)......Sakura-jima (Minami-dake).
N ......Nabe-yama.
(I)......Eruption from the W. side.
(II)......Eruption from the E. side.

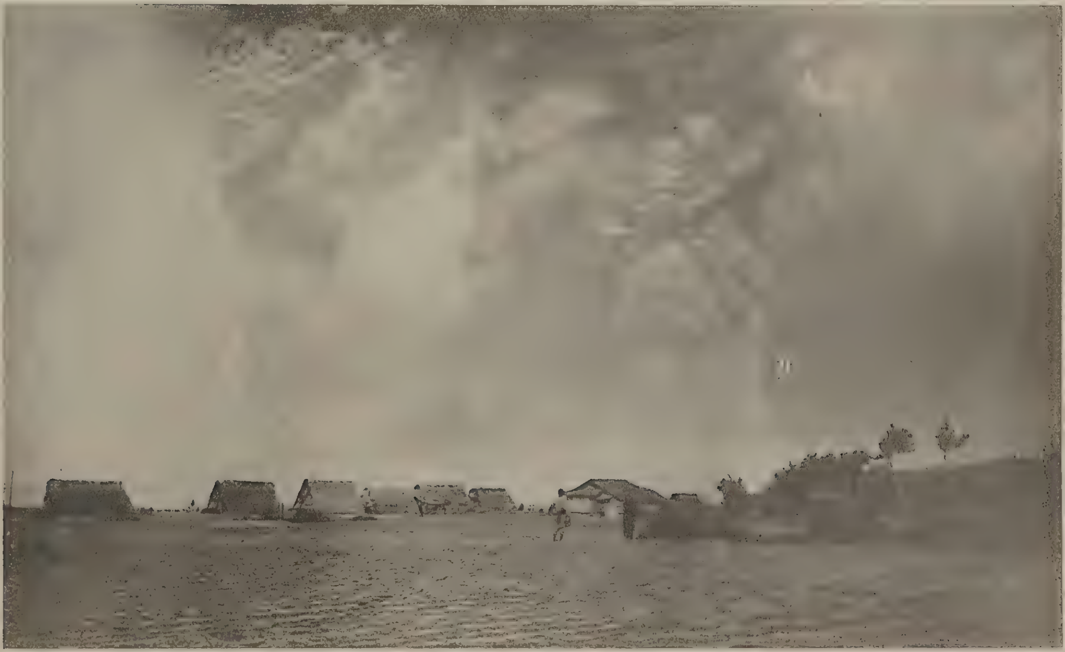


Fig. 7. View taken about 45 min. after the Commencement of the Eruption.

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Initial Phase of Sakura-jima Eruption. Seen from Shiroyama Hill Park, Kagoshima.

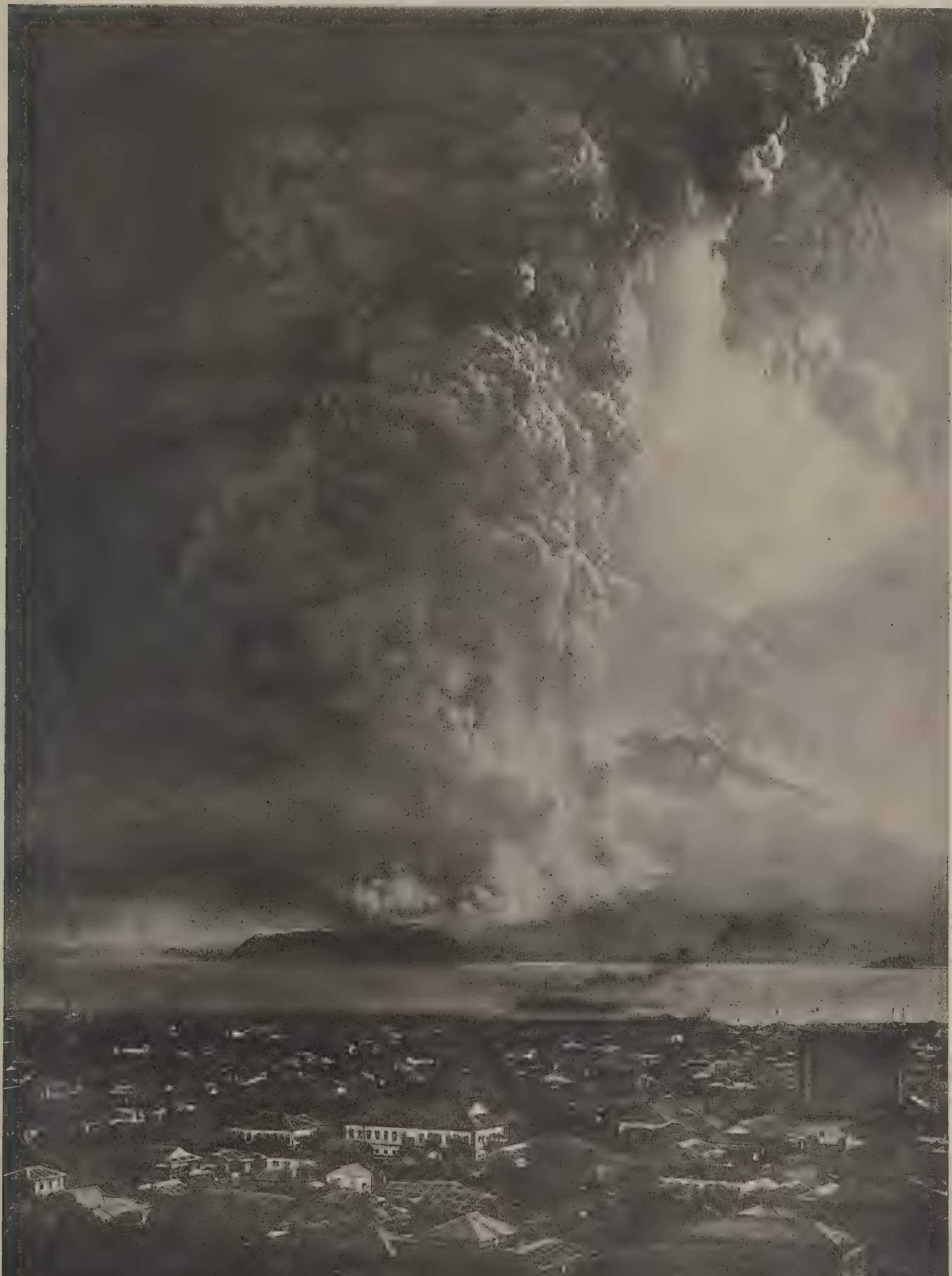

Fig. 8. View taken about 1 hour after the Commencement of the Eruption, or approximately at 11 a.m., on Jan. 12th, 1914.

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Sakura-jima before the Eruption of 1914.

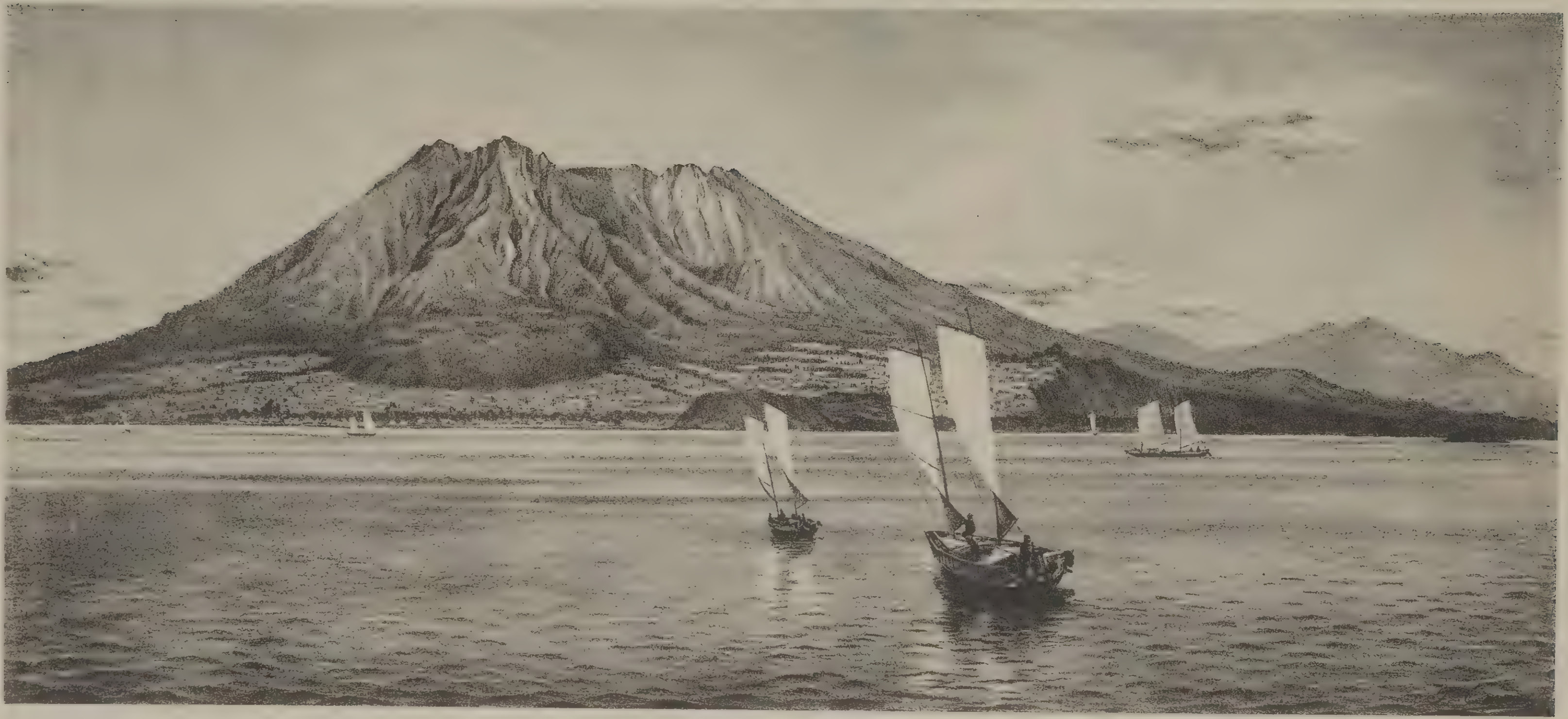

Fig. 9. Sakura-jima seen from Gion-no-su, the mouth of the Inari-gawa, at the N. part of Kagoshima. (From a sketch drawing made by Mr. Nanto Omure in 1909.)

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East and West Side Views of Sakura-jima. (1), Hakamagoshi. (×), Nabe-yama.

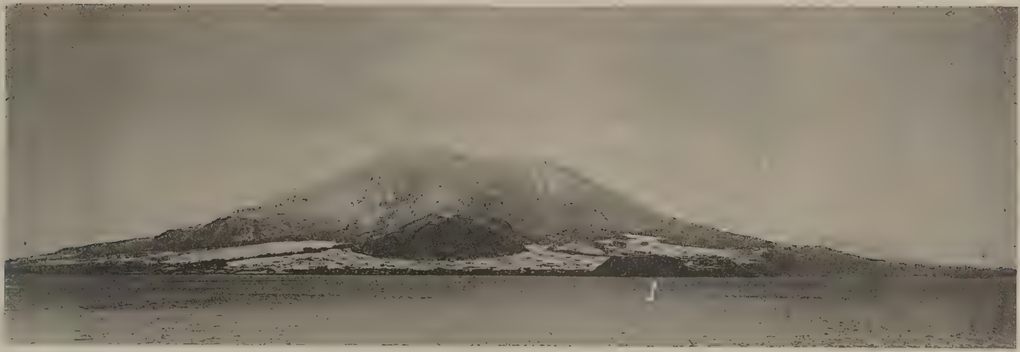

Fig. 10. W. side view after the snow fall taken from Gion-no-su, Kagoshima, on Jan. 8, 1914, namely, 4 days before the Eruption. (C. Sugimoto, photo.)

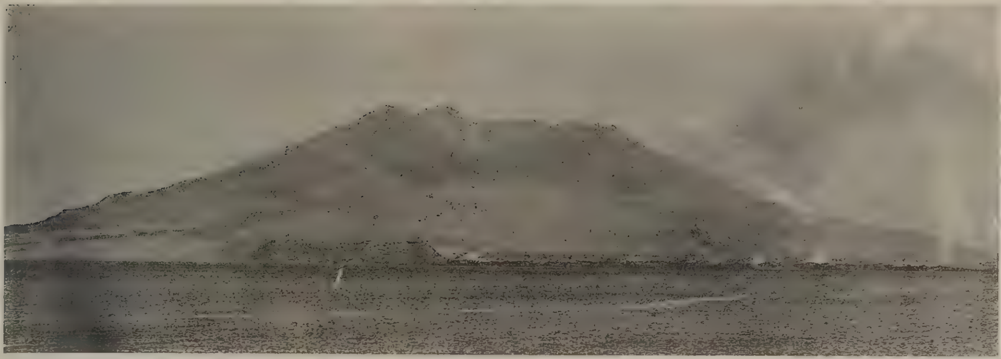

Fig. 11. View taken from nearly the same locality in Sept. 1915. (F. Omori, photo.)

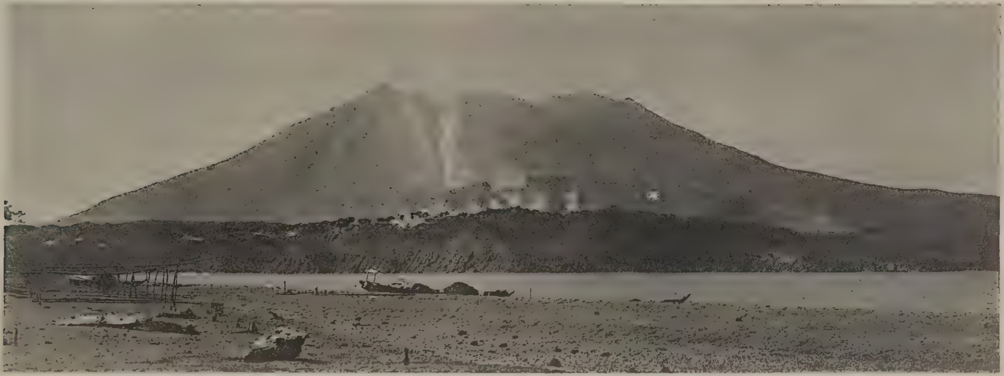

Fig. 12. E. side view taken from the shore of Ushine, indicating the annular Nabe-yama top behind the black lava bank at the front. (F. Omori, photo.)

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Sakura-jima in 1894. (Sketches by Dr. T. Suzuki.)

1……Minami-dake. 2……Naka-dake. 3……Kita-dake.
4……Nabe-yama. 5……Moe-jima. 6……Nakano-shima.

Fig. 13.

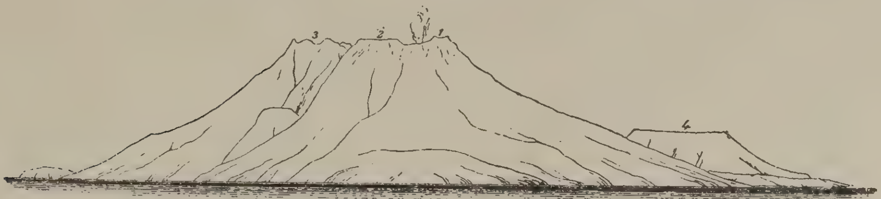

Fig. 14.

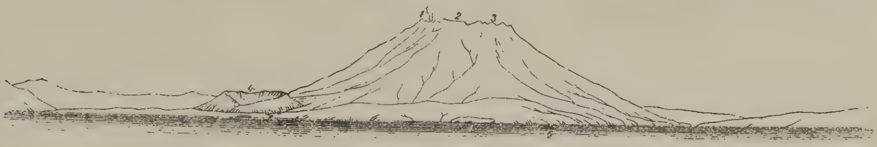

Fig. 13. View from Fukuyama 18 km to the N.E. of the centre of the island.
Fig. 14. View from Sesegushi 22 km to the S.W. of the centre of the island.

View of Sakura-jima, showing the change of form of Nabe-yama before and after the Eruption of 1914.
(1), Sakura-jima. (2), Nabe-yama. (3), Sakkabira.

Fig. 15.

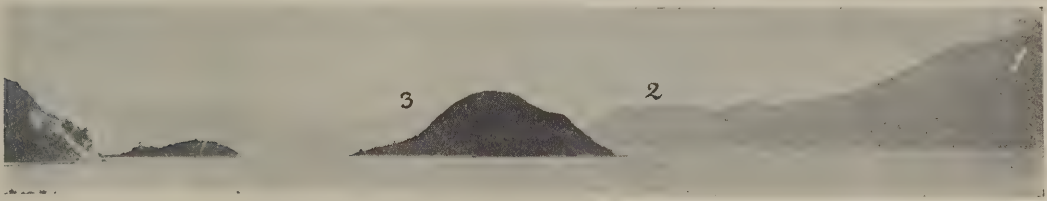

Fig. 16.

Fig. 17.

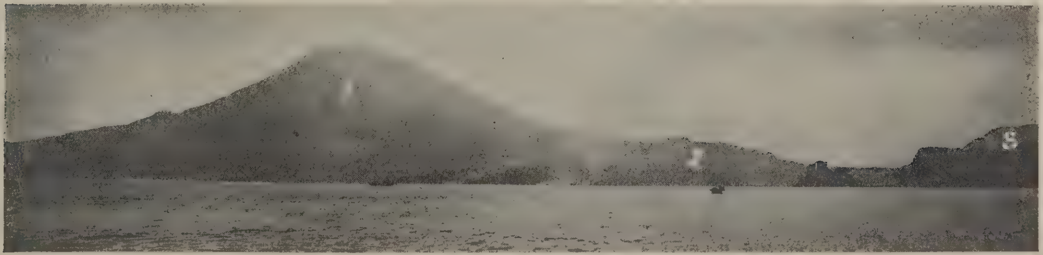

Fig. 15 Picture taken, some years before the Eruption, from Hamanoichi (near Kokbu, at the N. coast of Kagoshima Bay), showing Kanzukuri-jima at the centre, and Nabe-yama immediately to the right.
Fig. 16. Sakura-jima seen from the mouth of Shin-kawa, near Hamanoichi, with Nabe-vama at the left-hand side base. (Sept. 3rd, 1914. F. Omori, photo.)
Fig. 17. Sakura-jima seen from the S., with Nabe-yama at the right-hand side base. (Sept. 25th, 1914. F. Omori, photo.)

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The wall of the No. 4 craterlet is breached at the S. side, being there connected to a smaller secondary cavity No. 4′ (fig. 5), about 50 m in diameter, whose reddish inner side was constantly crumbling down. The cavity is separated from the black lava source only by a narrow ridge 228 m above sea-level, over which the air was still intensely flickering in Sept. 1915, and whose breadth was only 30 m. Below the No. 3 craterlet there are two more secondary craterlets Nos. 3′ and 3″ which are continued stepwise to No. 4′ at the lower level, together forming an inclined eruption fissure. (See fig. 75.)

3. Craterlets on eastern side. (Cont.) (See figs. 75, 87, and 88.)

Nabe-yama eruption crack: western portion. Proceeding 220 m eastwards from the No. 4 craterlet we reach, at the bottom of a gentle valley, the border of the shallow craterlet No. 5 (fig. 18), whose diameter is about 150 m, and where commences the western branch of the Nabe-yama Eruption Crack, entirely covered with lava fragments. 250 metres more along the southern border of the crack zone bring us to the foot of the S. shoulder of Nabe-yama, whose present top, 321 m above sea-level, is reached after an ascent of further 280 m. In the crack zone, about 150 m in breadth, there are a number of traces of shallow craterlets in addition to the one above noticed.

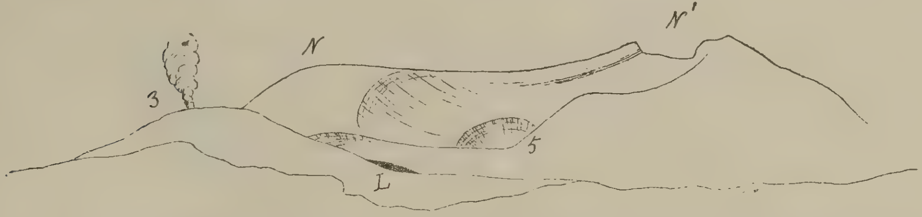


Fig. 18. Nabe-yama Eruption Crack seen from the West. (Sept. 27th, 1914.)
3.......Craterlet No. 3. N ......Highest point of Nabe-yama.
5.......Craterlet No. 5. N′......Highest part (opening) of Nabe-yama Eruption Crack.
L......Black Lava Source.

Nabe-yama eruption crack : eastern portion. The S. portion of the Nabe-yama U-ridge, which is crossed by the Eruption Crack, has been much shattered and considerably reduced in height, as may be seen from a comparison of the photographs (figs. 15 and 16) taken from the vicinity of Hamanoichi before and after the eruption of 1914. Thus, before the eruption the top AB of Nabe-yama was flat, while at present it is much inclined toward the east, (A′B′ in fig. 19). Estimating from the photograph (fig. 15), the height of the point B before the eruption comes out to be 358 m, being accidentally equal to that of the new trigonometrical station on the highest point of Nabe-yama, which must have suffered elevation and depression during and after the volcanic disturbances, besides being coated with an accumulation of the ejected material. The height of the new shoulder point A′, approximately corresponding in position to the former trigonometrical point

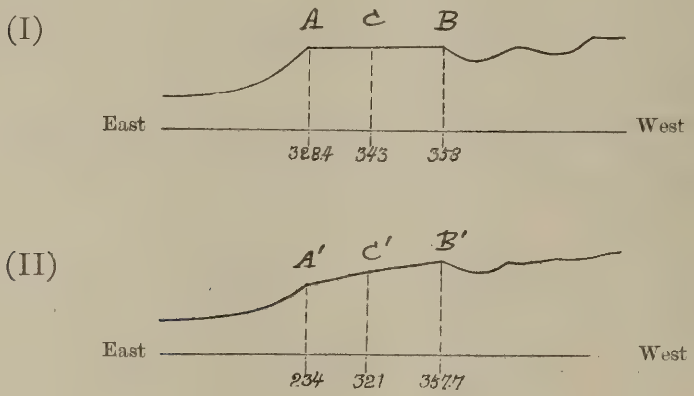


Fig. 19. Nabe-yama seen from North, (I) before and (II) after the Eruption of 1914.
AB (A′B′)......Nabe-yama top.
B......Highest point on the W. edge of the top ridge.
A...... " " " " E. " " " " "
C......Position of the present highest point on the S.E. side, or the top cliffs of the eruption crack.
[B′, C′, A′ correspond in position to B,C,A respectively.]

at A is about 234 m, the amount of truncation or height reduction being 94 m.

The eastern portion of the Eruption Crack is much deeper than the W. branch and is about 350 m in total length. At the head, 248 m above sea-level there is the large and regular circular explosion craterlet, No. 6, about 60 m in depth and 120 m in

Fig. 20.

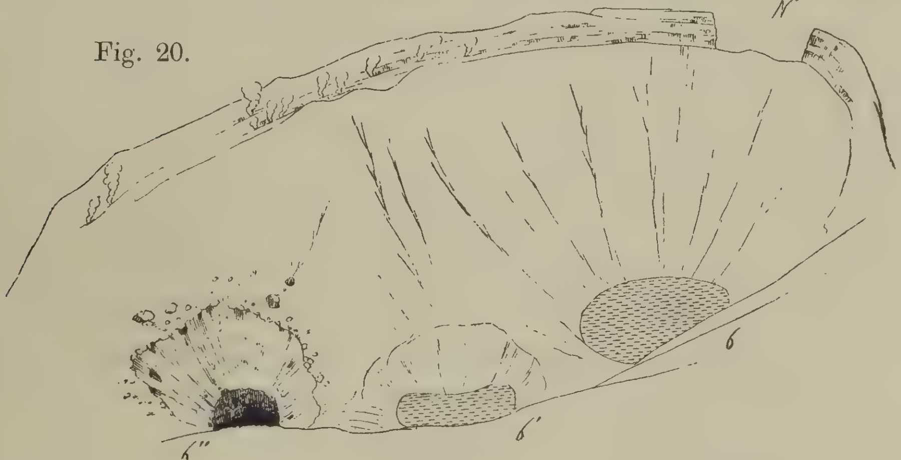
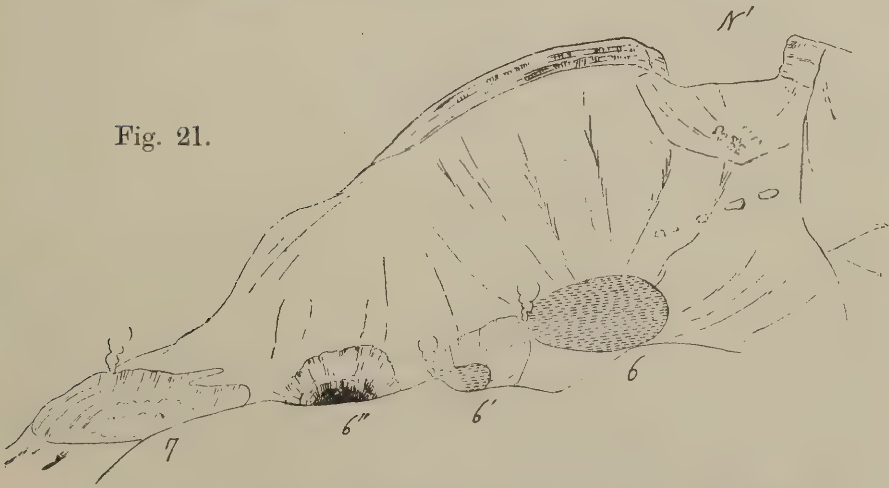


Fig. 21.



Figs. 20 and 21. Sketches illustrating the Arrangement of the Craterlets in the Eastern Portion of the Nabe-yama Eruption Crack. (May 3, 1915.)
6, 6′, 6″, and 7……Craterlets Nos. 6, 6′, 6″, and 7 respectively.
N′……Highest part (opening) of the Nabe-yama Eruption Crack.

diameter, formed out of the soft clayey or ashy material of Nabe-yama, the bottom being plane and filled with ashes and some water. It looked like the No. 4 craterlet already mentioned, and indicated no rock exposure on its inner conical side. Immediately below and continuous to this large hole, there is the small craterlet, No. 6′, about 20 m in diameter. At a slightly lower level, there is another small hole, the craterlet No. 6″. Separated from the lower end of the latter by an accumulation of lava masses, there is the craterlet, No. 7, an oblong elliptical cavity, about 60 m in width and 100 m in length, which extends within the height limits of 185 and 140 m above sea-level, and whose top layer has foundered, as is the case with the lava source below the No. 4 craterlet. At the upper end, there is a nearly circular opening more or less clearly separated from the rest of the craterlet bottom; this being evidently an orifice from which the new molten black lava flowed out, part of which still remains piled up outside the upper edge. The lower end of the craterlet, which looks like a dry dock, is blocked up by the successive layers of black solidified lava masses, outside which there expands the extensive lava fields on the Krokami side. (See the sketches in figs. 20 and 21, and the photograph in fig. 102.)

At the time of the present author's visit to these parts, on May 4th, 1915, the different craterlets were completely quiet, only slight columns of smokes rising from the upper and lower edges of No. 6′ and from the side edges of No. 7. Yet all along the slope forming the N. side of the Eruption Crack, the ground was hot, over 100° C in temperature, and series of solfataras were issuing along the entire margins.

4. Remarks on Nabe-yama eruption crack. At the east or highest boundary end of the W. portion of the Nabe-yama Eruption

Crack, below which lies the deep eastern portion, the two banks or sides form a sort of strait or gate opening, pq in figs. 24 and 25. (See also the photographs, figs. 77, 87, and 88.) The height of the two cliffs p and q is each about 12 m, while the width of the

Fig. 22.

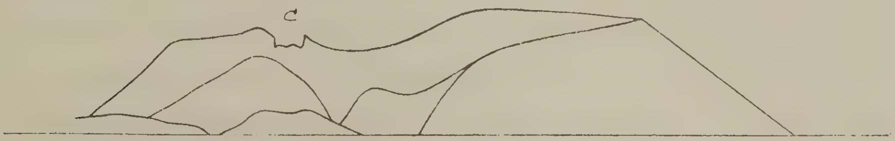


Fig. 23.

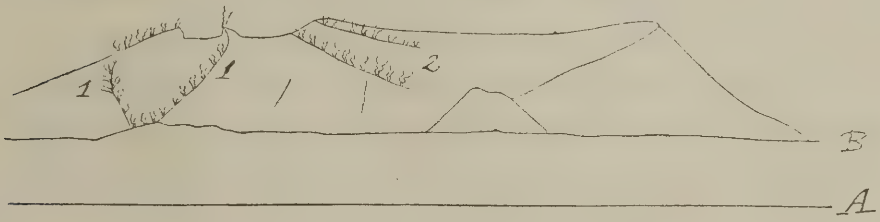


Fig. 24.

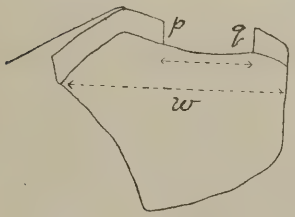


Fig. 25.

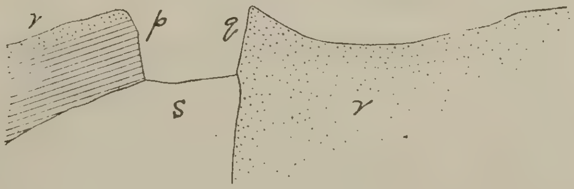


Fig. 22. Outline of Nabe-yama seen from East.
C = Top opening of Eruption Crack.

Fig. 23. Nabe-yama seen from East, showing the issue of small steam columns along the mouth boundary (1) of the eastern portion of Eruption Crack, and also along other fissures (2). (May 4, 1915.)
A = Sea-level. B = Plateau at base of Nabe-yama.

Fig. 24. Eastern Portion of Nabe-yama Eruption Crack seen from the front.
Width w = 100 m. p, q = Exposed edges of the lava layer.

Fig. 25. The Top Opening of Nabe-yama Eruption Crack, seen from East.
r = Lava layer covered by ashes. s = Bottom of Eruption Crack.

opening pq (fig. 24) is about 60 m. The margins of the eastern portion of the crack indicate an additional covering, which had at places yellowish incrustations, and along which smokes were everywhere issuing slightly. (See figs. 23 and 88.) This new layer, masked under the thick surface accumulation of ashes and rock fragments, seems to be nothing other than the coating formed by the lava which flowed over from the large craterlets Nos. 2 to 5 on the other side of the Eruption Crack, and of which a portion poured down into the central hollow space of Nabe-yama. The topmost opening pq is therefore not the result of an excavation, but in reality only a space formed by the exploding away of a portion of the new lava sheet.

The southern flank of Nabe-yama is dislocated at two different heights, giving out white smokes from numerous points situated along the crack lines. These steps are evidently the terminal sides of the sheets of lava outflow which were successively issued in the earlier stage of the eruption, probably from the craterlets Nos. 2, 3, 4, 5, and 6.

5. Lava pieces projected from eastern craterlets Nos. 3 and 4. Between the No. 2 and No. 3 craterlets there is no apparent direct canal communication, but the ground is much fissured, giving out sulphurous gases of strong and almost choking smell. The ground is thickly covered with dark gray angular lava blocks of various dimensions, as is the case with the higher portions of Asama-yama, there being not a small quantity of loose slaggy lavas of yellowish colour like those projected from the latter volcano on the occasion of the long-continued eruption on Oct. 2nd, 1911. There are also numerous flattened and partly crushed lava pieces of dark and slightly yellowish colours which resulted from the impact against the ground of the red-hot masses projected in plastic condition from the craterlets. A huge block of this sort measured about 41 feet or $12\frac{1}{2}$ m in length. Of the lava pieces projected out from the craterlet No. 3, a considerable proportion is deep red in colour, a fact limited to this neighbourhood.

On the slope ground to the south of the Eruption Fissure connecting the craterlets Nos. 3 and 4′, the loose blocks, several of which are large, are also very numerous; one of these, shown in fig. 41, is 2 m in height and $5\frac{1}{2}$ m in length, and has the shape of a crushed onion root. That these semi-breadcrust bombs, thrown out in the later stage of the eruption, are the results of comparatively feeble explosions, may be inferred from their small range of projection, which was limited to the distance of about 450 m from the south wall of the Eruption Fissure or the top of the slope in question. Further down the latter there are only hard lava fragments. The slope had first been covered by the lava outflow in the early stage of the eruption, the lower portion being thickly coated with ashes. For the upper 500 m of the slope, the ash layer was again buried under the volcanic sands of subsequent issue which were at the end of April, 1915, still so hot at several places as to render it impossible for us to stand there for a long time, due probably to the preservation of heat in the lava mass beneath. At one instance the sand temperature at 1 foot depth was 86°.3 C, while the simultaneous air temperature was 14.°2 C. Along crack lines, where slight fumaroles were issuing, the soil temperature was still higher. The reddish and black lava pieces found in these parts were not covered by ashes or sands, having been projected out at much later date. On the top of the same slope there remains a layer of lava, (*a* in fig. 26), about 3 m in thickness and 50 m in the downward extension; this being the remnant of the last overflow of the molten mass from the Eruption Fissure. (See the photograph in fig. 43.)

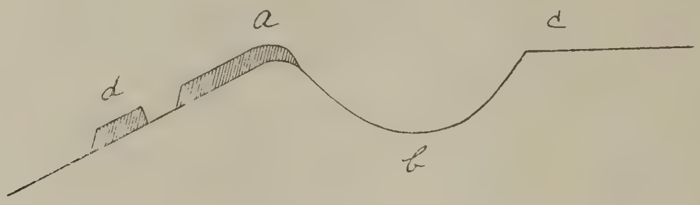


Fig. 26. Section illustrating the overflow of lava (a, d) from the Eruption Fissure (a b c).
d......Length = 5m ; thickness = 2m.

Remarks on plastic bombs. The "plastic bombs" seem to have characterized the last stage in the present Sakura-jima eruptions, when the magma at the bottom of the craterlets was no more pumiceous, that is to say, ceased to give out powerful jets of gases and steam, while the surface cooling was comparatively quick. In the case of Asama-yama, the projection of similar plastic bombs and lava fragments on the occasion of the long-continued outbursts on Oct. 2nd, 1912, marked the last as well as the first stage in its recent eruptive epoch, when the lava tended to flow out of the crater; the bottom of the latter having been elevated on that occasion almost to the brink.

6. Craterlets on western side. As remarked before, the No. 1 or highest craterlet is the only explosion cavity of perfect form existing on the western eruption field.

No. 1 craterlet. This has been formed inside the S. limb of a large U-shaped valley, evidently the site of an old explosion crater, which lies to the N. of Hikinohira and which opens westwards. The rim of the craterlet, whose height is 79 m and whose inside wall has an inclination angle of about 56°, is highest at the S.E.

and lowest at the W. side; the diameters of the mouth and the bottom being respectively about 174 and 63 m. The earlier stage of the outbursts here might possibly have been due to the formation of a number of small and shallow secondary explosion openings; a portion of one of these latter still remaining exposed to view at the top of the E. side wall of the craterlet. (See figs. 49 and 74.) As may be expected from the proximity of the heat area and the local lava reservoir mentioned in § 7, the large craterlet under consideration is exhibiting the residual activity in the form of numerous fumaroles, of which those near the Hikino-hira or S.E. side were specially energetic and had hissing sounds, the temperature being over 90° C in April-May, 1915. The whole bottom area, parched and not much buried with pumice, was then still very hot and there were more than one dozen of small shallow conical holes, of 4 m diameter and of 1 m depth in maximum size, many of which were dry and gave out steam and gases with a strong smell like that of vinegar. These had been formed probably by powerful emissions or miniature explosions of gas after the cessation of the stage of the principal outbursts and possibly later than the 20th of Jan., 1914. There were also fumaroles on the western inside slope of the craterlet, the

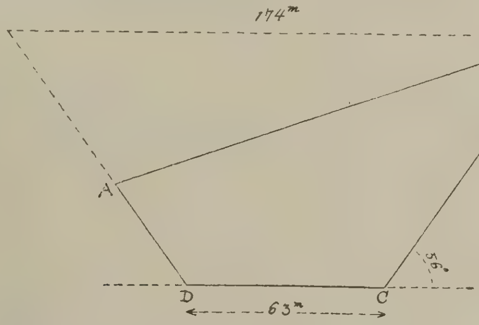


Fig. 27. NW-SE Section of the W. Side Craterlet No. 1.
Height differance, between B and C=79 m.

temperature measured on April 30th, 1914, being 88°.6 C. It may be remarked that the upper lip of the craterlet is 570 m above sea-level, or 135 m higher than that of the completely extinct No. 1 craterlet on the eastern or Nabe-yama side.

The ejecta from the craterlet seem to have been thrown mainly toward the W. where the wall is lowest, there being a great accumulation of hard lava blocks more or less in the form of bread-crust bombs, some of which are several metres in dimension. (See fig. 40.)

The western craterlet No. 1 is, in point of size, and was also probably in the violence of the explosion, inferior to none of the eastern craterlets, which latter indicate no trace of the "conical holes" at their bottom. It may be regarded as being equivalent to an explosive craterlet combined to an "eruption chimney", or the highest opening only for the emission of smokes which has been formed separately on the eastern eruption field (§ 2).

Lower craterlets series. The series of the lower craterlets (No. 4 in fig. 3, Pl. XXXIII.) forms a straight zone in the E.S.E. and W.N.W. direction, more than 400 m in length, along which have been formed amongst the others 4 more or less distinct shallow explosion holes. (See fig. 54.) The latter, of which the uppermost is the largest, are situated at heights of 100 to 160 m above sea-level, at a distance of about 400 m or more from the northern boundary of the lava area in these parts.

7. Lava sources. On the eastern eruption field there have been formed, besides the regular craterlets, in two cases also some fissures or orifices constituting the sources from which the molten mass flowed out continuously for some time interval. At one of these found immediately below the No. 4 craterlet at 220 m above sea-level, the latest and solidified lava issue of black colour remained in its position forming a sort of large elongated U-shaped mound, about 20 m in height, 50 m in width, and 150 m in length, which looks from side like a flat lava cone. (See the sketches in fig. 28 and the photograph in fig. 100.) The U, whose two limbs expand in the lower plane into an extensive fan-shaped lava field, had originally been an arched or vaulted grotto-like passage, whose roof crust along the central axis fell down, leaving on both sides traces of the springer formation more or less clearly. At the upper end of the mound in question there is exposed to view a small arched hole, this being the orifice of a shaft probably leading down to the lava reservoir under Nabe-yama Eruption Crack.

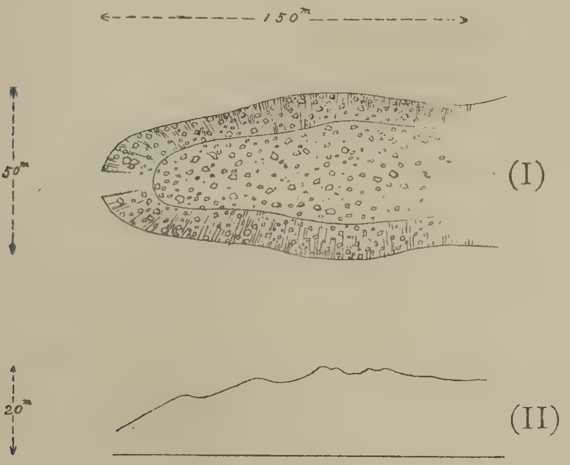


Fig. 28.
Lava Source below the Eastern No. 4′ Craterlet.

I......Plan.
II......Side outline.

On the western field of eruption, a typical massive and elongated lava source (figs. 51 and 52) remains in a well-preserved condition at a height of about 350 m above sea-level, 1 km to the N.W. of Hikinohira, and at the S.W. base of the 400 m hill above the village of Akobaru. When seen in April 1914, the outer curved layers of the lava crust were found partly peeled off at the top so as to resemble, in front or back view, somewhat a half-opened lotus flower in form.[1] During the active stage of the eruption, the mass of magma had been forced up there as well as at other points in the vicinity such that the ground above these lava sources must have suffered highly characteristic disturbances. Thus the small radial hill ridge forming the N. limit of the U-shaped valley, which opens westwards and in which the No. 1 craterlet is situated, has been much torn by longitudinal cracks and also by transverse ones; the latter being accompanied by successive stepwise dislocations, so as to present in a distant view an arrangement somewhat like the stripes on a tiger's back. (See figs. 50 and 29.) The lower end of this "lava head" is excessively broken up and becomes continuous with the actual lava source of the No. 2 vent. The whole hill ridge, almost from its upper end, or the junction with the top slope of Kita-dake, was giving out from different points small feeble columns of bluish-white fumes; the ground, which is parched and covered here and there with white or yellowish incrustations, causing much flickering of the air and having a high soil temperature of 90° to 100° C. The latter circumstances must indicate the existence at a shallow depth of the red-hot lava mass, as has been actually found out by the present author at the 3rd visit to Sakura-jima, in April-May, 1915.

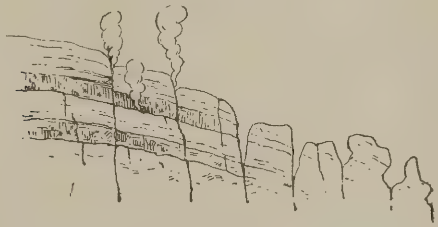


Fig. 29.

Side view diagram illustrating the successive stepwise dislocations of the ground immediately above the western lava source No. 2.

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(1) When visited in Sept. 1914, the thin outspreading parts of the lava source were found much broken down.

Thus at a point within the spot in question, 551 m above sea-level, the surface crustal portion had fallen in, forming an oblong cavity of mouth diameters of 15 and 8 feet, and extending obliquely to a depth of about 12 ft. At the bottom of the vault, continued to a sort of tunnel, evidently expanding toward the downslope, there was exposed to view a glowing red-hot surface of lava in the form of a semi-circle 5 ft in diameter, probably continued some distance into the passage. Small hard rock pieces, a few inches in dimension, thrown on the bright molten lava surface were turned into the same heated condition in the course of a few minutes, while pieces of wood were instantly set on fire even when thrown on the dark-red solidified part on the bottom in front of the molten mass. As the latter was perfectly stationary, it is evident that here we have to do with a case of a local lava reservoir, which is in a remarkable way situated at a height of 59 m over the bottom level of the craterlet No. 1, and which has preserved the fluid condition more than 1 year after the eruption. At the same time it is likely that a similar underground heat condition prevails in the neighbourhoods of the different craterlets on the western and eastern sides of Sakura-jima.

The cracking accompanied by the successive stepwise dislocations of a hill side may be partly the effects of an enormous underground expansive action or upward pressure (fig. 30) which has

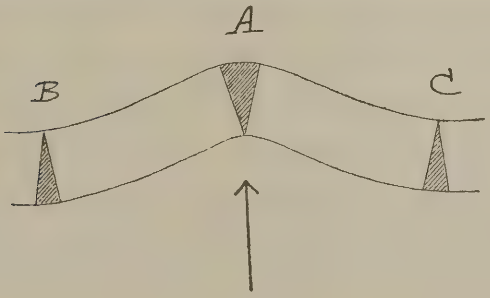

Fig. 30.

Sectional diagram showing the effect of the upward action of the underground lava mass.

A.........Open crack on ridge.
B, C......Fracture at valley parts.

even obliterated the existence of a narrow valley some 50 m in depth, formerly situated at the N. base of the above-mentioned hill ridge. Several of the small valleys in the higher part of Minami-dake (and also of the other two peaks) may be, not the results of mere erosions, but the sites of explosive craters or eruptive fissures formed ages ago. Again, it may be stated in connection with the origin of the elevated parts that the ridge to the S.E. of the 400 m hill immediately to the N. of the western No. 3 vent (lava source) has been in the recent eruption much torn by longitudinal and other cracks, which emitted hot fumes of strongly pungent smell. The absence of similar traces of disturbance at the base of the ridge seems to indicate that the latter was originally an upheaval formed by the upward pressure exercised by the magma at some former activity epochs of the volcano.[1] The top of the 360 m hill, extending in the N.-S. direction, which is situated to the W. of the above-referred 400 m hill, has also been much cracked by deep fissures pointing toward the centre of the island. These gave out vapours and are 1 to 2 feet in width, reaching down vertically 12 feet or so; but the real depth, which must be much greater, could not be ascertained, as the bottom has been filled up with fallen rock fragments.

8. Secondary craterlets. Apart from the western eruption field there were discovered by the present author on April 8th, 1914, two small secondary craterlets on the slope of the upper part of a narrow valley leading up from the village of Take (武) at an altitude of about 370 m, namely, at a distance of 1.0 km to the N. 25° W. of the centre of the No. 1 craterlet. (The position is

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(1) In the case of the Usu eruption of 1910, six small explosion craterlets were formed on the top of Nishi-Maruyama, a low round elevation, but none on the plane ground at its foot. This was probably due to the circumstance of the formation of the hill being similar to that supposed to be the case in Sakura-jima.

indicated by two small red dots in the map, Pl. IX, of the preceding Number of the Bulletin.) One of these, on the lower level, shown in fig. 48, is about 8 and 9 m in diameters and filled with reddish slaggy lava masses. Whether the latter had been forced up during the recent eruption or not, was not easy to decide. But the occurrence of a sort of miniature eruption from the hole in question, probably after the principal eruptive epoch, was indicated along the rim by the accumulation to a thickness of several inches of gray ashes, which presented a fresh appearance on the above-mentioned date; the temperature of the pumice layer around the mouth being also high and over 130° C. The two secondary craterlets together with a number of feeble steam issues were arranged along two nearly horizontal U-shaped crack lines, about 150 m in longitudinal extension. When visited again in September of the same year the holes were much filled up and indicated no heat phenomenon, the fumaroles in the vicinity having also disappeared. According to the accounts of Messrs. Ueda and Yamaguchi, of the Kagoshima Girls' Normal School, there has been in the ravine at the S.E. base of Hikinohira a slight outflow of lava apparently due to the recent eruption.

Ebinotsuka. Ebinotsuka is a beautifully-preserved small old ash and pumice cone of unknown date of formation, rising to the height of 122 m, and situated just outside the lava area on the plateau about 50 m above sea-level to the S.W. of the village of Krokami and approximately to the N.E. of Nabe-yama. The top ridge of the crater-wall, whose mouth diameter is 80 m and whose opening is directed toward the S.S.E., is much cracked and, when observed on Oct. 2nd 1914, issued feebly gases and steam. Amongst the others, there were several well-like depressions, from which some steam was rising. The greatest of these had a diameter of 3 m and the depth of not less than 6 m. It is probable that the recent great eruption produced fissures and other underground or surface disturbances in the region neighbouring the new actual craterlets.

9. Depression cavity. The level of the molten lava, which is pushed up in a volcanic conduit during the activity of eruption phenomena, necessarily settles down with the decline of the latter. In a large open crater, like that of Asama-yama or of Ō-shima (Izu), the depression of the central portion of the extensive bottom leaves behind in this way an annular portion or terrace along the circumference. If the conduit be narrow the depression may result in the formation of a sort of hollow well or shaft, whose top may or may not be exposed to view. In the case of the recent Sakura-jima eruption, the depression cavities were formed on the eastern eruption field in the craterlet No. 6″, in the craterlet No. 4, and at the lava source below the latter.

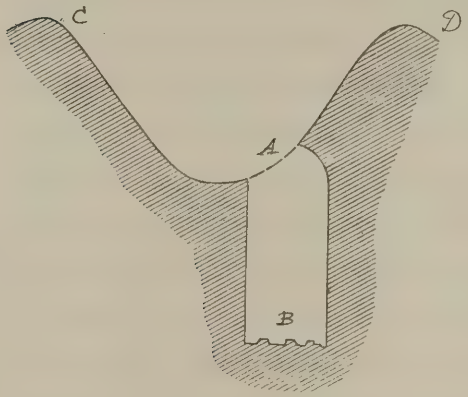

Fig. 31.

Depression Cavity at the Bottom of the Craterlet No. 6″ in the Eastern Portion of the Nabe-yama Eruption Crack.

C, D......Respectively the N. and S. edges of the eruption crack.

A, B......Top and bottom of the depression cavity.

The inside roof of the vertical cavity, about 15 m in diameter, formed at the bottom of the craterlet No. 6″, which was partly visible from the north edge of the Nabe-yama Eruption Crack, constitutes a sort of vault with great many short, and more or less columnar, lava projections hunging down from it (fig. 101). Small rock fragments thrown, by way of experiment, horizontally from the edge (C, fig. 31), reached the floor A in 3.0 sec., while others similarly thrown required 4.5 sec. in reaching the invisible shaft bottom B, the arrival thereon being indicated by the sound of impact. Estimating from these time observations, with suitable correction on the effect of the air resistance, the depth AB of the shaft is found to be about 40 m. A vertical lava hole about 10 m in diameter (and, when seen in April 1914, some 20 m in depth) formed close to the lower rim of the eastern No. 1 craterlet may also be the result of a similar depression process.

The depression cavity formed at the bottom of the eastern No. 4 craterlet, which is highly characteristic, has been discovered first at my visit there on Sept. 22nd, 1915. At the time of my previous trip, on April 23rd, in the same year, there was at the craterlet bottom a small mass of lava which had an appearance of the accumulation of loose fragments fallen from the side wall. (See fig. 91.) In reality, however, this was a protuberance of the molten lava out of the conduit below, being the result of the last eruptive effort of the magma, probably at the end of 1914, when the latter could no longer be projected up into the air. The lava mass in question had probably been already cracked vertically about or some time before April 1915, as a series of small dust explosions took place from the craterlet No. 4 on May 5th of the same year. (See § 21.) The cracking might possibly have been actually formed on that occasion. The final result was the subsidence of the whole N. vertical half of the lava mass, the section exposing to view a sort of compact inner column tapering upwards, some 30 m in height and supported by a beautiful spherical vault, about 15 m in diameter. (See the photograph, fig. 99.) In the dark bottom space could be seen another inside roofing with dislocations at top, this probably forming a sort of tunnel whose lower end was in communication with the lava source below the No. 4′ craterlet.

The roof of a depression lava cavity, in case it remains unbroken, may be more or less spherical. Thus, if AB (fig. 32) represents a volcanic conduit, the fluid magma will be forced up in a series of front surfaces 1, 2, 3, 4, 5, ...; the portion 4–5, cracked into a number of separate blocks, forming an arch or a vault, which remains behind, if sufficiently strong, after the lava mass in the conduit have sunk. In the case of a general depression of the central portion of the lava area filling a large crater bottom (AB..., fig. 33), a series of the cavities may be formed along the dislocation boundary B, C, ... exposing to view the back-side half of a cave

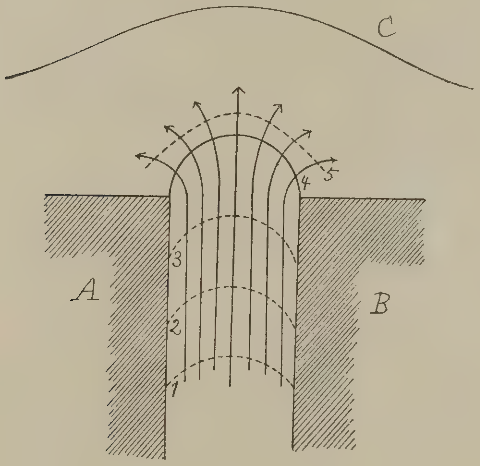

Fig. 32. Sectional Diagram illustrating the formation of an Internal Depression Cavity with Vaulted Roof.

C......Lava surface. Arrows indicate the direction of lava flow.

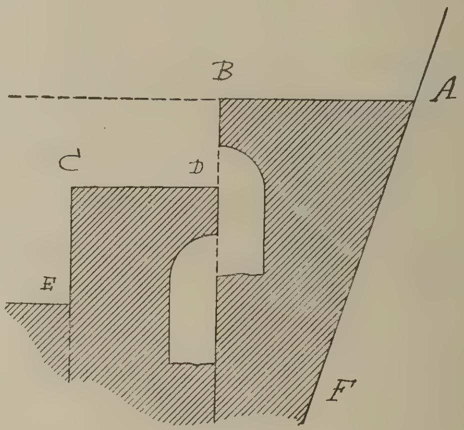

Fig. 33. A Diametral Section of a circular Crater filled with molten lava.

AB......Level reached by the molten lava.
AF......Crater wall.
B,C,.....Places of successive dislocations, resulting in level depressions D,E,......
D........Depression cavity.

or vault, D, E, ... This is exactly what took place in the crater of the Ō-shima volcano after the eruptions in 1912.

10. Amount of depression of lava level. (*A*) *Eastern lava field.* In the eastern portion of the Nabe-yama Eruption Crack, the lowest rim and the bottom of the craterlet No. 7 are respectively about 140 and 110 m above sea-level. The level of the mouth of the depression cavity of the craterlet No. 6″ is 160 m, while that of its bottom was, in Sept. 1915, about 120 m. Again, the bottom of the craterlet No. 4 is at a level of 250 m, the lava surface under it having been depressed several dozen metres further down. The lava source below the last mentioned craterlet is at a height of about 220 m, the bottom of its tunnel or shaft being further down. As the height of the uppermost limit of the lava overflow about the No. 1 craterlet is 430 m, it follows that the surface of the magma under the volcano elevated to the latter level at the commencement of the eruption has been lowered after its conclusion probably to a height of 110 m, or through a vertical distance of 320 m. In Sept. and Oct., 1914, when the craterlets Nos. 3 and 4 still maintained the firework-like eruptions of lava, the level of the latter was probably kept at a height of some 250 m above sea-level. (*B*) *Western lava field.* The uppermost lava sources were formed at heights of 400 to 500 m, while the lowest craterlets were at heights of only about 65 m; the vertical distance difference amounting here also to more than 335 m. It thus seems that on the whole the magma was upheaved during the eruption, in round number, some 350 m over the final depressed level of its crustal surface, the actual top of the inside molten lava being probably some distance further below. Hence it would be no exaggeration to suppose the total amount of the depression of the lava level after the eruption to be 500 m. In other words, the molten lava mass under the Minami-dake crater exists at ordinary times probably at the depth corresponding to the sea-level.

By way of examples, it may be noted that after the great Asama-yama eruption of 1783, when the "Oni-oshidashi" lava flowed out over the N. rim of the central crater (diameter=400 m) the bottom of the latter has sunk to a depth of some 300 m. Again, after the Ō-shima eruption of 1777, when an enormous amount of lava flowed out of the central crater (diameter=600 m), the bottom has subsided some 120 m.

11. Process of eruption. The majority of earthquakes which occurred in Sakura-jima previous to, and during, the recent eruption were probably the results of creating or enlarging the zone of volcanic fracture, in the way of preparation for the ensuing outbursts. The premonitory explosion at 8 a.m. on Jan. 12th, 1914, when a column of white vapour was projected up from the Minami-dake crater, may possibly denote the completion of the upper extension of the underground plane of disturbance. At the same time it is likely that there are a number of old fissures or narrow communications in the filled up conduit of Minami-dake, as is evinced by the existence of fumaroles inside and outside the top walls; it being not necessary to suppose that the new inside fracture reached up to the bottom of the crater.

The greater amount of lava outflow from, as well as the longer duration of the activity of, the eastern side craterlets is probably to be attributed to a greater width of the fracture zone in that direction; this supposition being apparently supported by the fact that there exists on the east side the broad Eruption Canal between the craterlets Nos. 2, 3, and 4, and also by the formation of the remarkable Nabe-yama Eruption Crack. Mr. Perret maintains that the speedy extinction of the eruptive

Sakura jima Eruption of 1914: Pumice layer floating on sea surface.

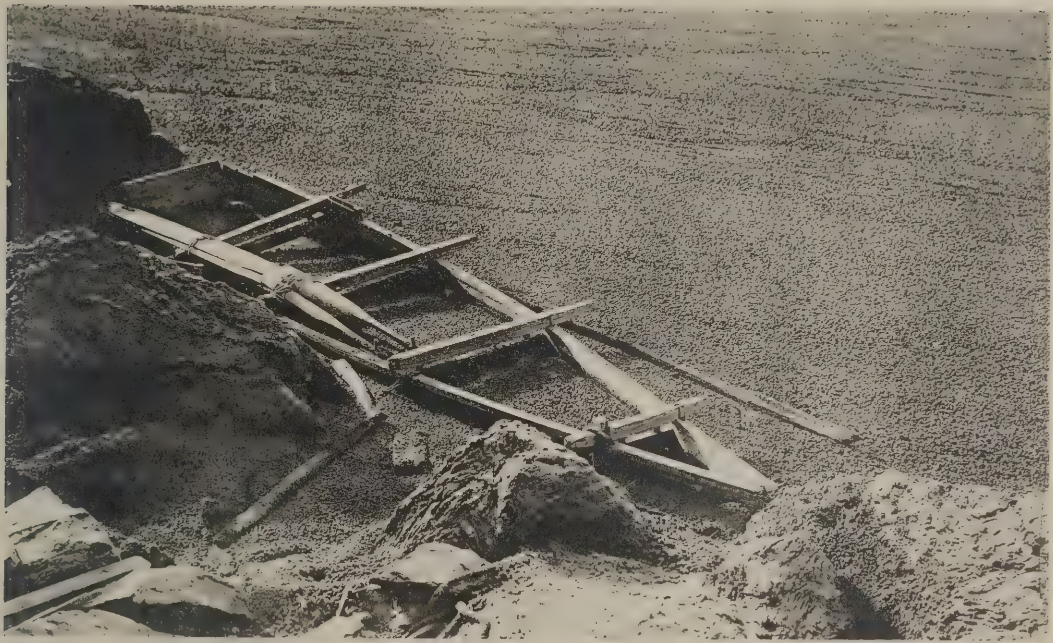

Fig. 34. A boat nearly submerged in the floating pumice layer at Koike on the W. coast of Sakura-jima. (Yuki, photo.)

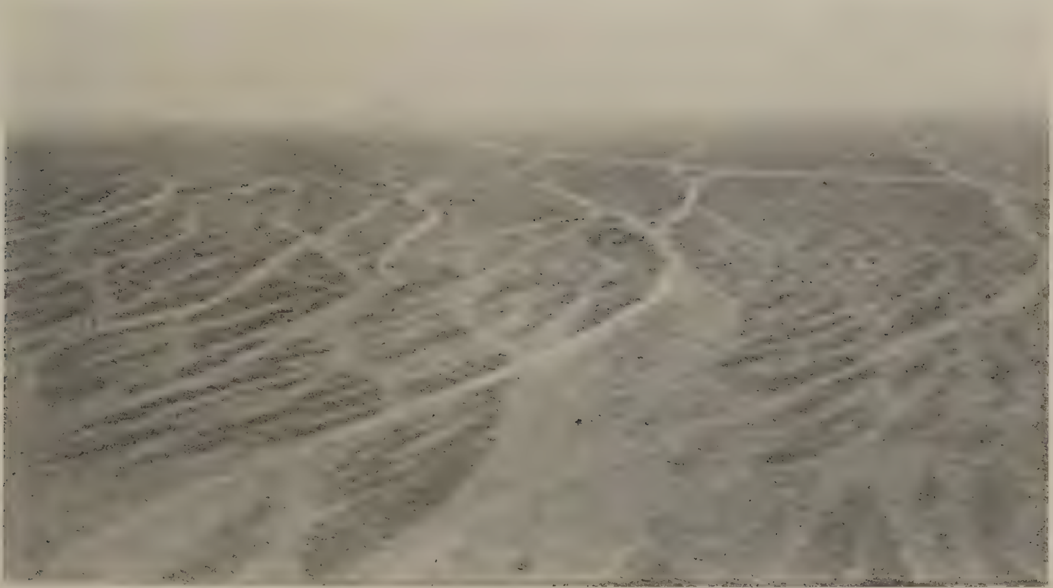

Fig. 35. Floating Pumice Layer outside the Harbour of Kagoshima. The precipitation of ashes rendered the torpedo-boat destroyer Shiratsuyu at a near distance dimly discernible. (Jan. 19th, 1914. F. Omori, photo.)

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Sakura-jima Eruption of 1914.

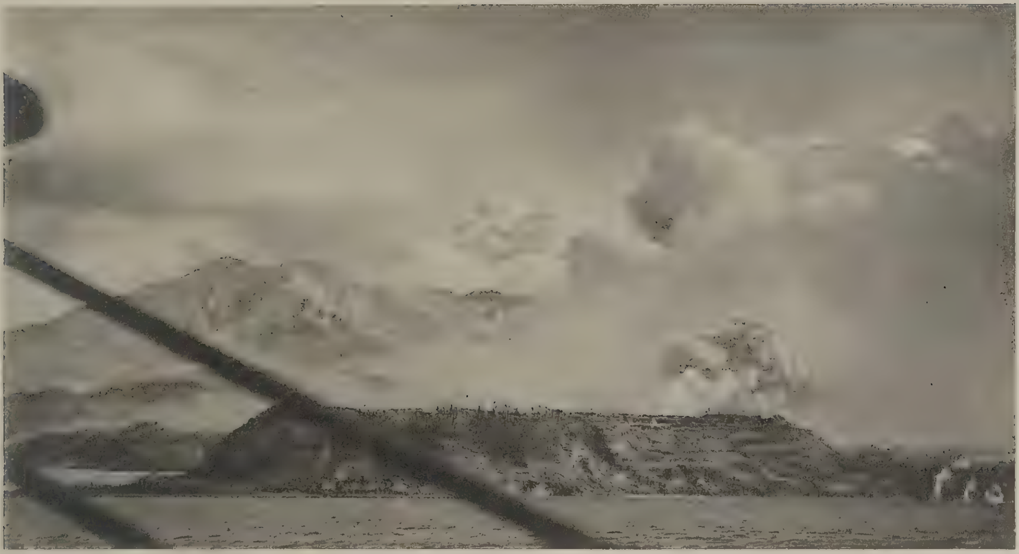

Fig. 36. W. side view of Sakura-jima taken while sailing in Kagoshima Strait on board the steamer *Nishiki-maru*, with the trapezium platform of Hakamagoshi at the front. (Jan. 19th, 1914. F. Omori, photo.)

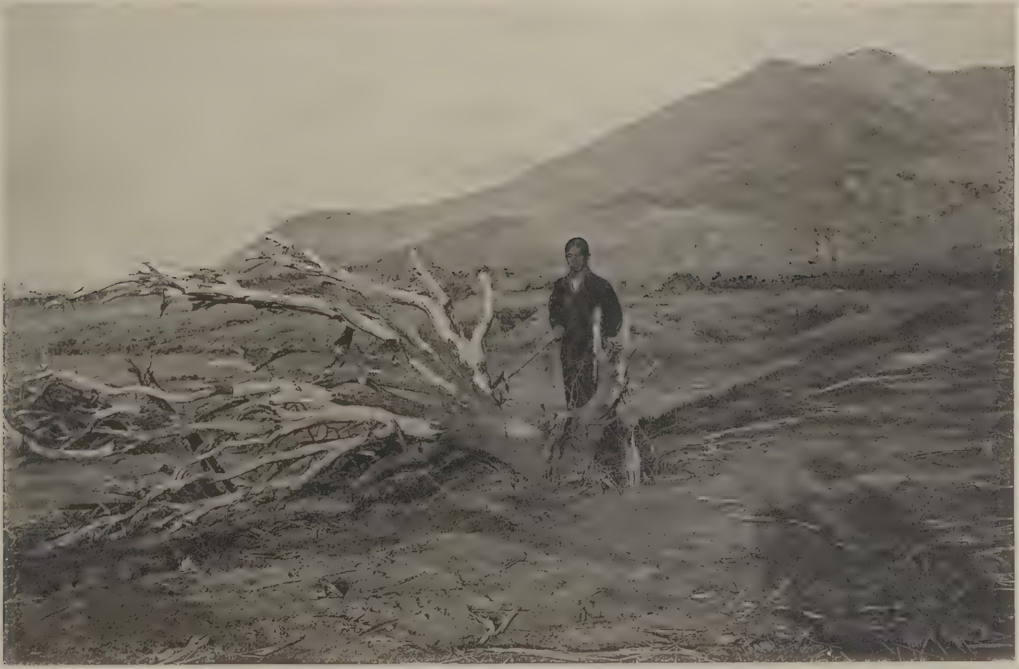

Fig. 37. W. side of Sakura-jima seen from the top of Hakamagoshi, indicating a large mandarine-orange tree uprooted and carried from the village ground below to the plateau by the force of the Eruption Blasts. (April, 1914. F. Omori, photo.)

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Sakura jima Eruption of 1914 : Thick Accumulation of Ashes in the E. part of Sakura jima.

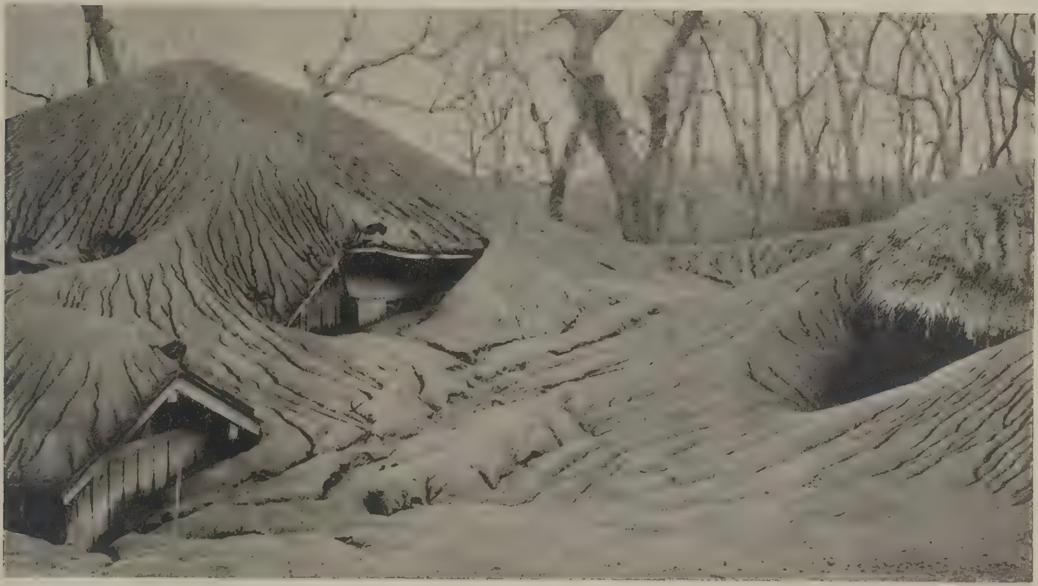

Fig. 38. Houses at Krokami buried in ashes. (March 16th, 1914. F. A. Perrett, photo.)

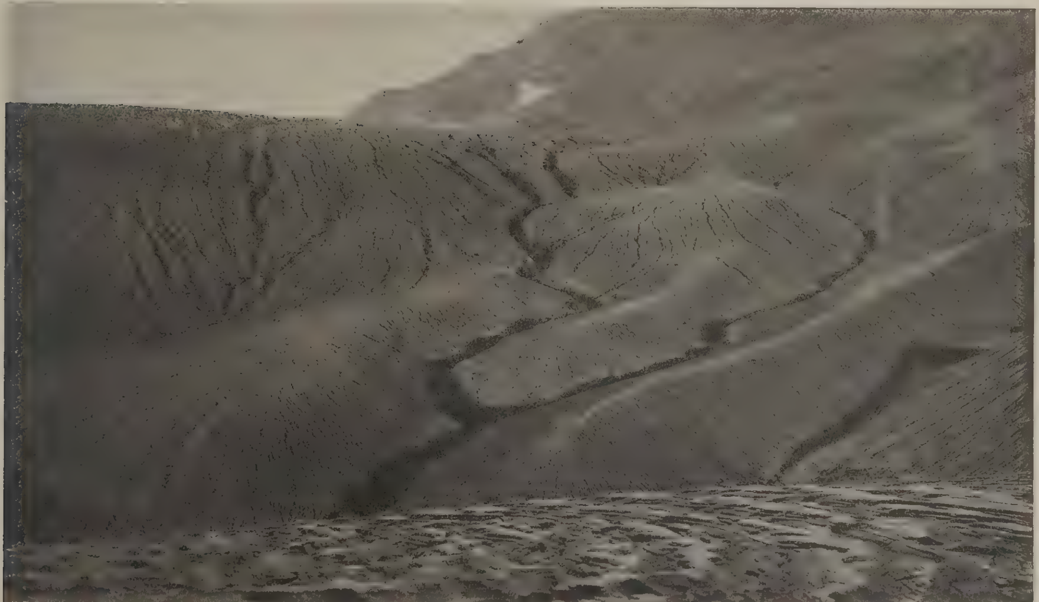

Fig. 39. Slope ground to the N.W. of Nabe-yama, seen from Gongen-yama, indicating the new layer of ashes cut into fine grooves by rain. (April, 1915. F. Omori, photo.)

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Lava masses projected in semi-plastic state in the later stage of the Eruption of 1914.
(April 1915. F. Omori, photo.)

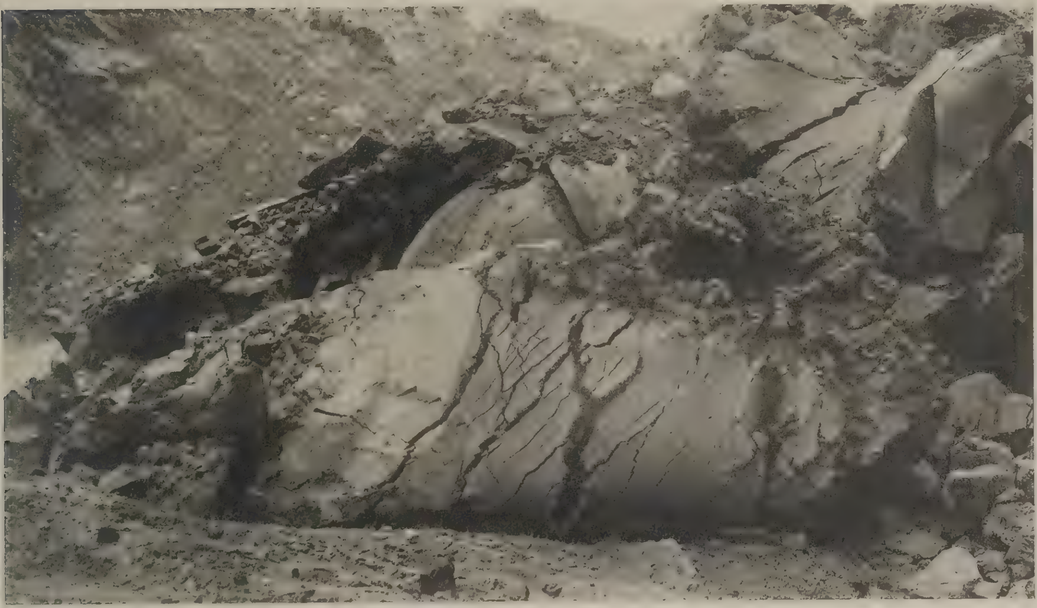

Fig. 40. Condition at the bottom of the Western No. 1 Craterlet.

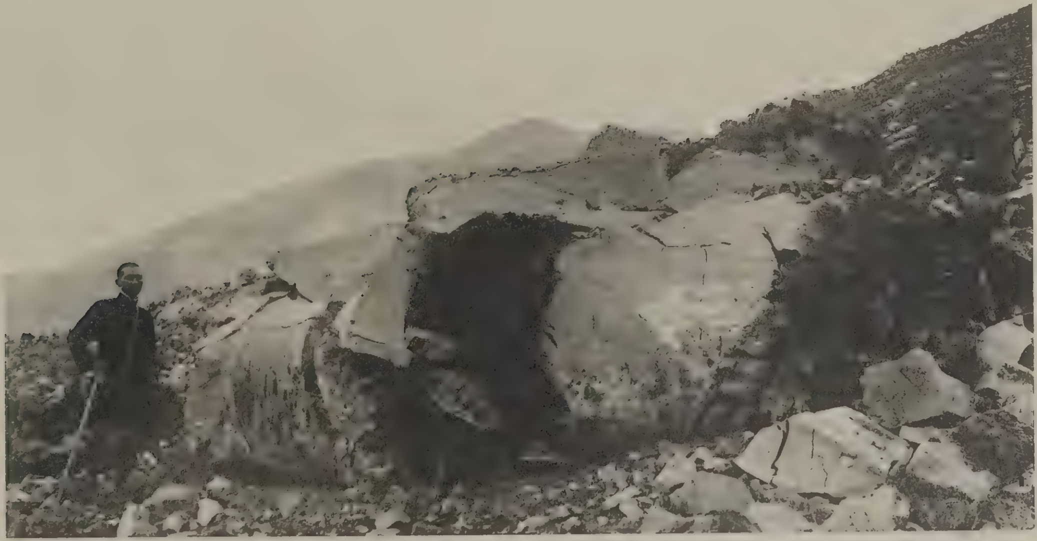

Fig. 41. A large flat crushed lava disc found on the slope forming the S. side of the Eruption Fissure connecting the Eastern Craterlets Nos. 3 and 4′.

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Lava masses projected in the later stage of the Eruption of 1914. (April, 1915. F. Omori, photo.)

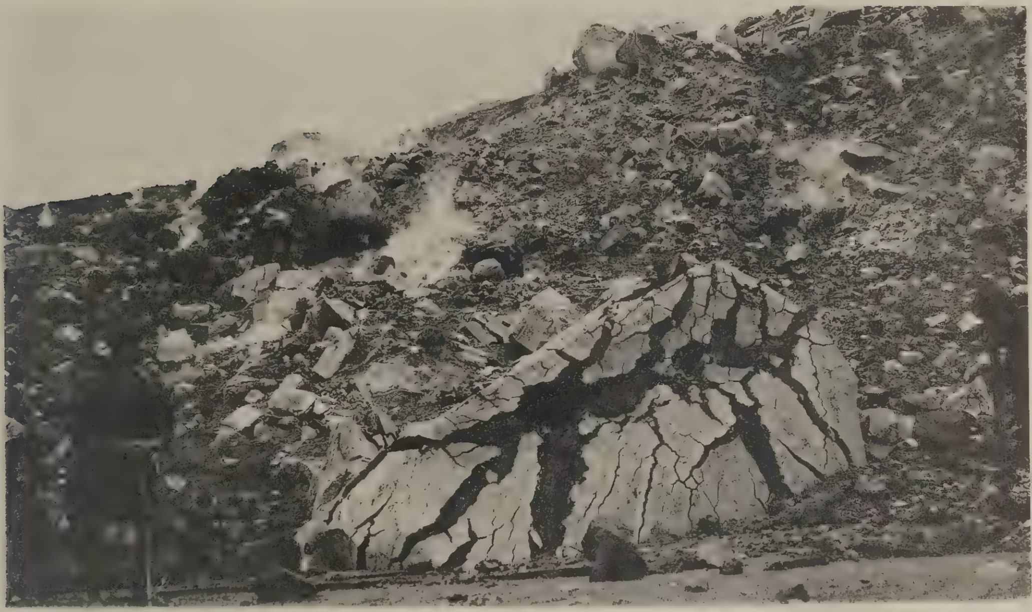

Fig. 42. A large bread-crust bomb found at the S. rim of the Eastern Craterlet No. 2.

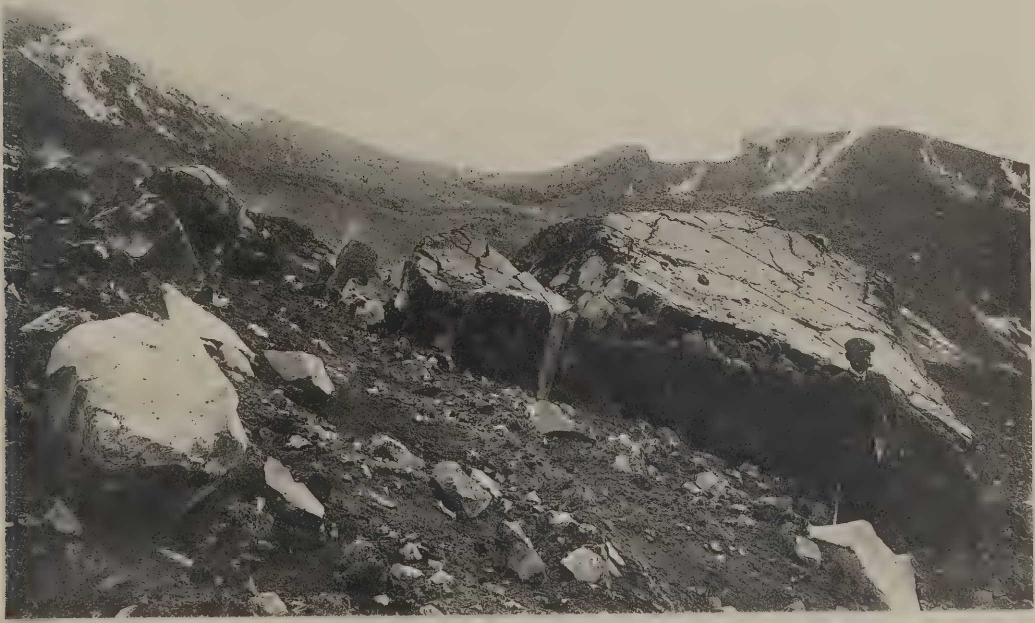

Fig. 43. Platy projection or overflow on the sloping S. side rim of the Eruption Fissure connecting the Eastern Craterlets Nos. 3 and 4'.

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disturbances on the west side was due to the formation of the lower craterlets along a valley region, whereby their mouths must have been blocked up by the lava streams flowing down from the higher levels. Similar effects, however, must have taken place to a certain extent also at the east side in the case of the No. 2 craterlet and with those openings in the E. and W. branches of the Nabe-yama Eruption Crack. On the whole, it looks probable that in the present instance the eruptive activity was really greater along the E. than along the W. side craterlets zone.

As will be seen from figs. 2 and 3, the highest explosive vents were formed on both flanks of Minami-dake a little below its half height, namely, about the lower boundary of the upper and steeper portion of the mountain which is nearly symmetrical with respect to the N.-S. direction. The upper boundary of the western eruption field is, however, 100 metres higher than that of the eastern. With this height difference might probably have been connected the apparently greater explosive violence of the initial outbursts on the western side. The existence on the eastern flank of the separate "chimney" or No. 1′ vent for steam and gases also probably contributed to reduce the explosive force of the craterlets on that side.

The greater height of the western craterlet No. 1 is evidently due to the existence of, or the coincidence in position with, an elevated ridge (I in figs. 1 and 3), which is connected with the dome-like hill of Hikinohira, and which is probably the result of an upheaval in some past epoch of the volcanic activity, it being assumed that the formation of a volcanic orifice and the forcing up of the lava take place with a greater facility under a ridge than under a valley (§ 7).

Chapter II. Activity Variation.

12. Commencement of eruption. Figs. 6 and 7 are the pictures of the eruptions from the two opposite sides of Sakura-jima taken by Mr. R. Higo, of Tarumizu, on the morning of Jan. 12th, 1914, respectively at about $10\frac{1}{4}$ and $10\frac{2}{3}$ a.m., or probably some 20 and 45 minutes after the very commencement of the eruption. The interesting sketches (figs. 44 and 45), made by Mr. S. Bando, of Shibushi Middle School, give the *approximate* state of smoke emissions during the earlier stages of the eruption as observed by him from the south while proceeding on board the steamboat "Tatsu-maru" from Kagoshima to Furue, a town on the west coast of Ōsumi about 22 km to the S.S.E. of Sakura-jima. According to fig. 44 the first outburst which was accompanied by no detonative sound took place on the W. side from the highest No. 1 craterlet (situated to the north of Hikinohira, 570 m above sea-level), followed by the 2nd outburst from a craterlet at a lower

Approximate Views of Sakura-jima from the South immediately after the Commencement of the Eruption.

Fig. 44.

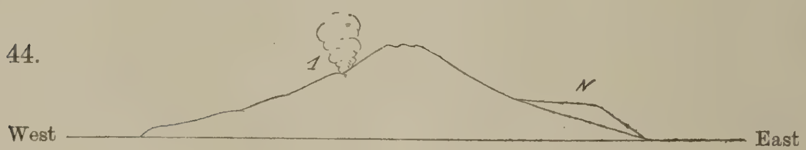
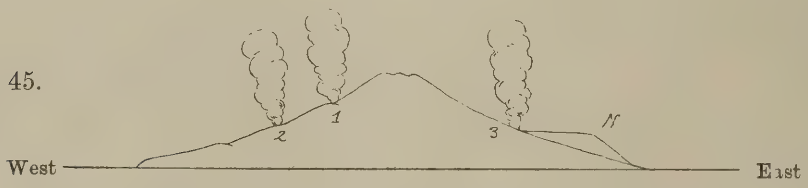


Fig. 45.



N......Nabe-yama. 1, 2, and 3 indicate the order of outbursts, corresponding respectively to the craterlets Nos. 1 and 2 on the west side, and No. 1 on the east side.

place, probably located in the neighbourhood of the Gongen shrine 400 m above sea-level. Then the eruption began from the highest No. 1 craterlet on the east side. In fig. 6 the smokes from the latter side, still from a single mouth, has ascended vertically about 1130 m, namely, has attained the height of about 1560 m above sea-level, while those on the W. side formed a vertical column about 1150 m in the E.–W. diameter and ascended already to a height over 5000 m. In fig. 7, the smokes from the east side forms a vertical column about 1300 m in the E.–W. diameter. So far Nabe-yama, shown at the right hand side of fig. 6, remained unaffected, the eruptions on the east side perhaps taking place principally from the craterlets Nos. 1 and 2, and on the west side from the openings, not much lower than the top of the above-mentioned hill, or over the height of some 330 m above sea-level. As yet the outbursts were not very explosive, the detonations having been heard in Kagoshima first at 3.30 p.m. (12th). Between $10\frac{2}{3}$ p.m., 12th, and 8 a.m., 13th, when the explosive action was at the climax, the smokes must have reached a height probably of about 10 km. From figs. 6 and 7 it will be observed that the ashes were carried toward the N.E. or E.N.E., as the front of the western smokes advanced to the right behind the eastern smoke column; the eruption zone, or the line joining the craterlets on both flanks of the mountain, making an angle of 45° with the direction connecting Tarumizu and Sakura-jima.

Fig. 8 is the view of Sakura-jima taken from the Shiroyama park in Kagoshima probably about one hour after the commencement of the eruption, showing the trapezium plateau of Hakamagoshi at the left-hand and the small islet of Karasu-jima (buried under the lava later on) at the right-hand side. On the front or the west mountain slope, the dense eruptive smokes rose vertically in a column of the N.–S. diameter of some 900 and 1500 m respectively at base and top; there being projected from the craterlets a great many hot lava pieces with a white trailing tail of gas and vapour.

According to the accounts of the municipal officials and the school masters of Tarumizu, the houses in the villages of Arimra and Waki on the S.E. coast of Sakura-jima were burnt at 2 p.m. on the first day of the eruption. At the same time the whole space about Nabe-yama was enveloped in black smokes, it being supposed by some that the lava outflow did then began. From 4 p.m. on the same day burning lava pieces fell on the sea, splashing the water high into the air. The lava stream is supposed to have reached the sea already at 10 a.m. on the 13th. If so, the lava would have run down the distance of 2.3 km from the craterlets Nos. 1 and 2 to the coast at Arimra in the course of some 20 hours, with the average speed of 110 metres/hour. At Obama, a place on the coast of the province of Ōsumi at a distance of 4.7 km to the S.E. of the eastern No. 1 craterlet, forest undergrowths were put on fire at 4 p.m., 12th, from the precipitation of the burning stones; the conflagration was, however, put out after 1 hour by the fire brigade of the village.

13. Eruption blasts. Unmistakable signs of the generation of volcanic blasts were observed on and around the plateau of Hakamagoshi. Thus, according to our observations on Jan. 19th, 1914, on the village ground inside the latter, the school house had entirely been destroyed and carried off somewhere in pieces, there remaining only the foundation timbers, immersed in a pool of water dammed by the lava stream. The beach at the S. side of Hakamagoshi was strewn with broken timbers. On the farm grounds at the top of Hakamagoshi 72 m above sea-level, there

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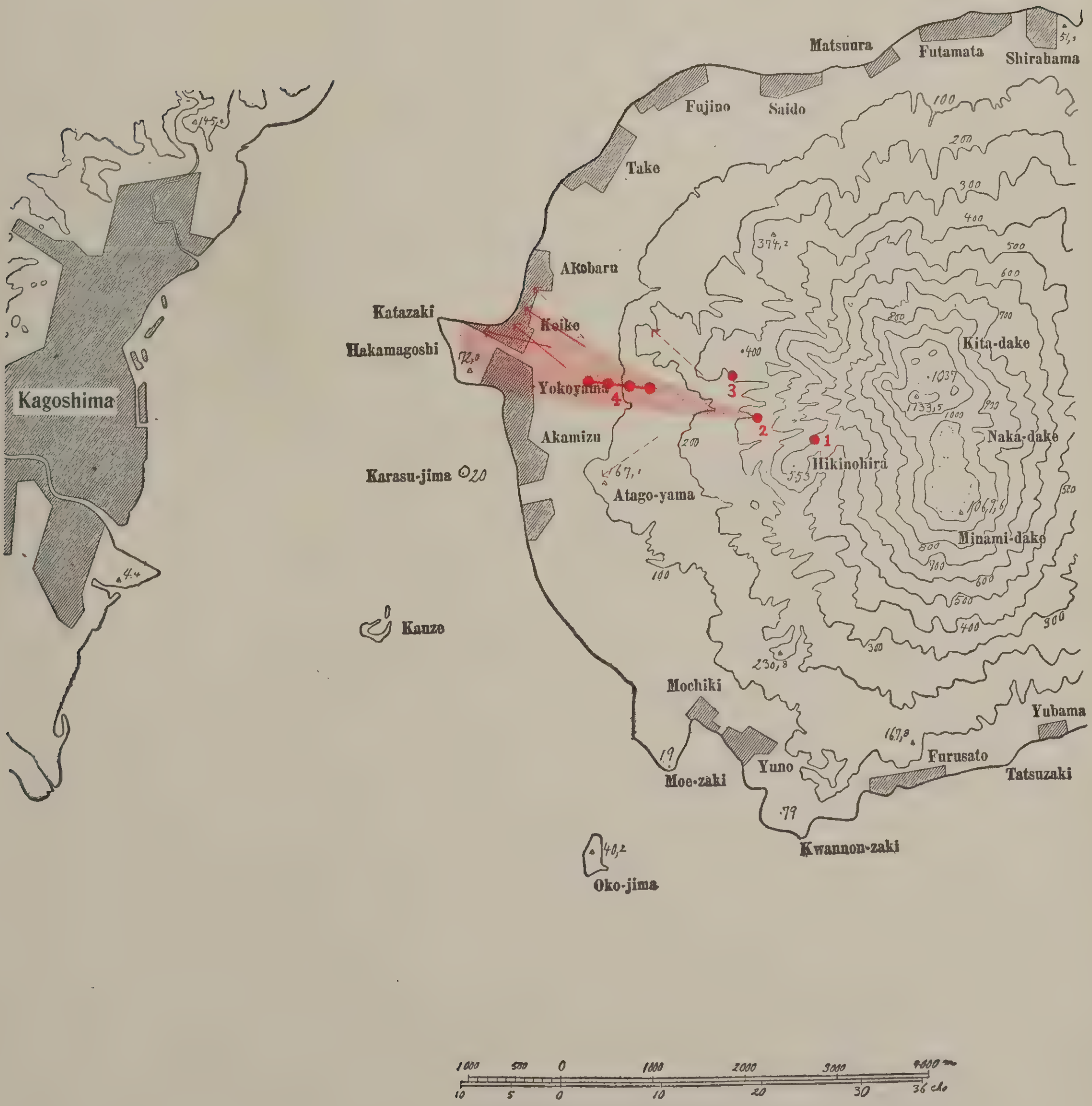
Fig. 46. Map showing the Direction of the Volcanic Blasts on the Western Eruption Field.

Red arrow...Direction of the blast.

Do., dotted···Direction of lava block projection.

The thin red shade indicates the district where the blasts were strong. The red dots 1 2, 3 and 4 mark the positions of the western craterlets Nos. 1, 2, 3 and 4.



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were found, besides a considerable quantity of timbers shattered from the houses, a great number of large uprooted mandarin-orange trees which had been carried westwards by the blasts through an upslope distance of 300 m or more from the village of Yokoyama situated below at the east foot of the plateau in question. (See fig. 37.) The sugar-canes on Hakamagoshi were found entirely thrown down, mostly outwards or away from the centre of the disturbance, although the cases of the contrary direction were also not wanting.

On the N. slope of Hakamagoshi, the majority of the trees were standing, even though burnt and charred. On the N.E. corner and on the E. side, however, the trees were mostly overthrown, the demarcation of the damaged and undamaged regions being quite sharp. At the south portion of the E. side slope of Hakamagoshi several slender trees were standing. It thus seems that in the region under consideration the volcanic blasts were directed principally against the N.E. corner of Hakamagoshi and toward the adjacent village of Koike. On the ground about the latter, the destruction was general and the tree trunks were mostly overthrown or broken toward the old fort ground of Gion-no-su at the mouth of the Inari river at the north end of the city of Kagoshima, and a factory building near Prince Shimazu's Iso mansion, or midway between these, i.e., in the directions varying from N.73°W. to N.52°W. These two limiting directions point, if produced backwards, respectively to the western No.1 craterlet and the lowest active craterlet behind Hakamagoshi. Several trees, whose bark remained intact even on the side facing the source of disturbance, were found overthrown toward the Gion-no-su, very probably by the volcanic blasts. On the fields behind the village of Koike and at the N.E.

base of Hakamagoshi, the trees were found overthrown mostly away from the Minami-dake. A large camphor tree, about 3 feet in diameter, which had stood in the ground of a shrine at the boundary of Koike and Akobaru, was overthrown toward N.55°E., which direction, if produced backwards, points to the uppermost of the craterlet series lying to the S.W. of the hill group above Akobaru, (the craterlet No.4 in fig.2, in the preceding Number of the Bulletin). Again, at the mandarin-orange grove to the N. of the cemetery in Akobaru, the trees, completely stripped of bark on the side facing S.E., were overthrown toward the opposite direction, namely, toward the N.39°W., which, if produced backwards, passes through the lowest of the craterlets belonging to the series above noted. (See fig. 46.)

On the top of Atago-yama, 166 m in height, situated 2.0 km to the S.E. of Hakamagoshi, the large tree trunks were uniformly overthrown or broken in the direction of the islet of Kanze, namely, toward S. 57° W.; this direction prolonged backwards points toward the lava source at the S.W. foot of the 400 m hill (the craterlet No.3 in the map, fig.2, in the preceding Number of the Bulletin.) The trees were completely stripped of bark on the side facing the centre of disturbance by the impact with the lava projectiles. The Atago shrine itself was destroyed and carried somewhere by the stones and the blasts, leaving behind no trace at all. For the width of about 100 m along the foot of the steep S.W. slope of Atago-yama the trees were found overthrown.

At the vicinity of the cemetery in the beach ground of Akamizu, the young pine trees about 9 feet in height were burnt and partially charred, but not broken or uprooted. A similar effect was also observed at the base of the lava outflow to the north of Nojiri.

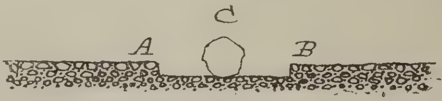
On the eastern eruption field, distinct trace of the blast can be recognized neither on the plain districts of Krokami to the north of Nabe-yama, nor even on the slope grounds above the village of Furusato and immediately below the craterlet No. 1. It is hereby to be remarked that the different craterlets on the east side are located on elevated positions constituting ridges, while those on the west side were formed on the whole along the trough of a V-shaped radial valley opening westwards. This last circumstance has probably allowed the partial westward concentration of the explosive effects, resulting in the formation of the eruption blasts which swept against Hakamagoshi and the vicinity, and whose direction was there essentially identical with that of the projection of the lava blocks from the craterlets concerned.

14. Holes produced by the impact of lava blocks. On the flat beach to the N. of Hakamagoshi, where the ground was not much covered by large pumice pieces, the conical holes formed by the impact of the projected lava blocks were very numerous, their space distribution being such that, in one instance, about 75 were counted in a rectangular area 83 m in length and 64 m in width, with the average of one in every 70 sq. m. The diameter of the holes was from $1\frac{1}{3}$ to 3 m. On the field at the back of the village of Koike and on the N.E. base of Hakamagoshi, the conical holes were very numerous, being literally consecutive one with the other. At the boundary of the village districts of Koike and Akobaru there were no conical holes to be observed, having been, if any, hidden from view by the layer of pumice blocks, from a few inches to 1 foot or more in dimension, which accumulated to the thickness of 2 to $2\frac{1}{2}$ feet. (See fig. 56.) On the top ground of Hakamagoshi there were a great many holes, the largest of which had the diameter of 8 m and the depth of 1½ m. On the hilly grounds above the villages of Akobaru and Take, conical holes of maximum diameter of 3½ m were formed on the new pumice layer, whose depth was 0.54 m. On the ground in the vicinity of the cemetery of Akamizu, to the south of Hakamagoshi, there were no conical holes formed by the falling stones.

At the foot of Nabe-yama, behind the village of Krokami, there were several conical holes formed on the pumice and ash field, the maximum diameter being about 2 m.

Small lava pieces falling on the ground covered by a hardened layer of pumice produced a splashing about of the latter, which according to what was observed in April 1914 below the eastern No. 1 craterlet, resulted in the formation of shallow uniform-depth holes. Thus in one case, (fig. 47), the fallen rock fragment C was 6 inches in size, while the hole A B was 1 inch in depth and 2 feet in diameter.

Fig. 47.



In the days immediately succeeding the eruption there were found, at the outside base of Hakamagoshi, more than 20 dead horses and pigs, which had been driven out of the villages of Yokoyama and Koike burnt and otherwise destroyed and there struck by burning lava fragments or suffocated by hot eruption blasts. On Jan. 19th, 1914, there was found a large stiffened dead eel on the dried sea-beach, while, on the lower portion of the S. slope of Hakamagoshi, where the soil was moist, there were great many dead toads, all stiffened and dried up in a climbing posture, having probably been scorched by the volcanic heat. On the inner side of Hakamagoshi, several dead pigs were found among the burnt remnants of the houses of Yokoyama.

15. Pumice. On the débris-covered grounds about the villages of Koike and Akobaru, to the N.E. of Hakamagoshi, larger lava blocks were found to form the upper layers, while small pumice pieces, sands, and ashes formed the lower layers. This would indicate that the finer constituents of the volcanic ejecta were given out during the earlier stages of the eruption, followed by the coarser fragments later on ; it being these latter which set on fire the houses of the neighbouring villages. The houses in Yokoyama and Koike situated near Hakamagoshi were being burnt already on the 12th, at about 6½ p.m., while at the more distant villages of Take and Fujino several houses were burnt on the night of the 13th.

On Jan. 18th, 1914, the floating pumice area in Kagoshima Bay encountered by the torpedo-boat destroyers *Shiratsuyu* and *Ikazuchi* to the N.W. of Sakura-jima was about 3 miles in length and 1½ miles in width.

On the morning of Jan. 19th, 1914, the wind being easterly, there was a slight precipitation of ashes in the city of Kagoshima, which rendered the air very dusky, the detonative sounds also being there perceived quite intensely. At 10½ a.m., when the author and his party started on a tour in the bay on board the training vessel *Nishiki Maru*, the floating pumice filled the harbour and covered the outside sea surface for several miles, completely surrounding the two torpedo-boat destroyers lying there at anchor. Landing on Sakura-jima and coming back to Koike at 4½ p.m., it was found that a layer of pumice about 10 inches in thickness had completely blocked up the coast from the base of Hakamagoshi to the vicinity of the villages of Fujino and Saido at the N. W. part of the island. The efforts of 4 stout students were perfectly ineffective to drive through the area of pumice a small boat, in which we had come in the morning, so that it was partly pushed by men standing in the water and partly pulled with a rope from the steamer, until we were finally enabled to embark the latter. Where the accumulation was comparatively thin and broken by the undulatory motion of the sea, fish often jumped up and, remaining on surface of the pumice layer, could not again get into the water.

At the beach the floating pumice often proved deceitful to the horses and even to the men, who, on account of the difficulty of recognizing the demarcation between land and water, trod sometimes into the latter.

16. Eruptive sounds. In the earlier days of the eruption the volcanic sounds occurred of course at close intervals. In the city of Kagoshima, which is situated westwards at the minimum distance of about 5 km from the lowest (nearest) craterlet on the western side, the sounds were sometimes very loud and like the booming of guns, constituting what may be termed a sound shock, namely, a strong air disturbance which caused marked shakings of the houses. At other times, the sounds were like the rushing of winds, accompanied by movements more or less. There were also cases, in which the sound waves ceased to be audible, and yet caused some shakings of the *shojis*, or paper-covered sliding doors in Japanese houses. The duration of the sounds, which was usually quite short, was in several instances more or less lengthened, up to about 40 sec.

The perception of the eruptive sounds in Kagoshima depended, like the precipitation of the ashes, much on the state of the weathers. Thus the easterly winds invariably brought in the city some diffusion of the volcanic dusts and an increase both in the intensity and the frequency of the detonations, causing alarm each time to the panic-stricken inhabitants. At Tarumizu and other places in the province of Ōsumi, situated eastwards from the volcano, the sounds were heard much more intensely than in Kagoshima. The following table contains only a fragmentary list of the sounds which I have accidentally perceived in Kagoshima or Tarumizu on Jan. 17th, 19th, and 21st–26th, 1914.

TABLE I. Observation of Volcanic Sounds.

Place of Observation.	Date (1914).	Time of Occurrence.	Remarks.
Satsumaya Hotel, Kagoshima.	Jan. 17.	10.42.13 p.m.	Strong detonation.
		11.20.20	Air shakings.
Do.	Jan. 19.	8.48.45 p.m.	Very loud sound shock.
		8.49.33	*Do.*
		8.55.42	Rushing sound, not very loud.
		9.05.52	Booming sound, not very loud.
		9.06.25	,, ,,
		9.08.28	,, ,,
		9.09.44	,, ,,
		9.10.08	*Shojis* shaken, accompanied by no sound.
		9.10.39	Sound, faint.
		9.12.12	,, , ,,
		9.13.05	,, , very faint.
		9.37.20	Sound rather loud, long in duration.

TABLE I. *(Continued.)*

Place of Observation.	Date (1914).	Time of Occurrence.	Remarks.
Satsumaya Hotel, Kagoshima.	Jan. 19.	9.41.10 p.m.	Loud sound, continued for 40 sec.
		9.43.54	Very loud, but short in duration.
		10.16.00	Sound.
		10.25.20	*Shojis* shaken, without sound.
		10.28.29	,, ,,
		10.29.53	,, ,,
		10.39.37 p.m.	,, ,,
		10.40.48	*Shojis* shaken, followed by dull sound.
		10.52.51 p.m.	Sharp loud sound.
		11.08.20	Strong air shakings, without sound.
		11.38.48	Rather loud, with some shaking effects.
Girls' Normal School, Kagoshima.	Jan. 21.	3.13.12 p.m.	Loud sound.
Satsumaya Hotel, Kagoshima.	*Do.*	6.57.36 p.m.	Loud rushing sound, accompanied by shaking of *shojis.*
		7.03.27	*Do.*
		10.14.29 p.m.	Very loud detonation.
		10.34.05 p.m.	Faint rushing sound, with slight shaking effect.
		10.34.30	Rushing sound.
		10.34.40	*Do.*
		10.34.55	*Do.*, continued for 5 sec.
		10.35.20	*Do.*
		10.35.30	*Shojis* faintly shaken.

TABLE I. (*Continued.*)

Place of Observation.	Date (1914).	Time of Occurrence.	Remarks.
Satsumaya Hotel, Kagoshima.	Jan. 21.	10.35.46 p.m.	*Shojis* faintly shaken.
		10.39.10 p.m.	Slight rushing sound; *shojis* shaken once.
		10.41.08	*Do.*
	Jan. 22.	7.33.06 a.m.	Loud booming sound, shaking *shojis*.
		7.34.34	Feeble sound, shaking *shojis*.
		7.47.54 p.m.	Loud detonation.
		10.50.30	*Do.*
	Jan. 23.	2.20.37 a.m.	Loud booming sound.
	Jan. 24.	7.16.30 a.m.	Detonation, causing shaking of *shojis*.
Tarumizu Municipal Office.	*Do.*	3.19.03 p.m.	A very loud booming detonation, which though said not to be rare in Tarumizu, was the strongest I have so far experienced, there being also sharp shaking effects. This sound due to an explosion from one of the eastern craterlets, was also loudly perceived in Kagoshima.
Satsumaya Hotel, Kagoshima.	*Do.*	6.55.51 p.m.	Shaking of *shojis*, with no sound.
		11.07.10	Some shakings of *shojis* with no noise; followed by another after a short interval.
Kagoshima Harbour.	Jan. 25.	6.34.28 a.m.	*Shojis* shaken; no sound.
		11.10.57	Loud detonation due to an explosion on the western side.
Satsumaya Hotel, Kagoshima.	Jan. 26.	9.01.01 a.m.	Strong detonation, with shaking effects. This sound was also perceived at Miyazaki, where soon after black clouds were observed on the S.W. sky.

The time interval between the moment of appearance of the eruption flash from among the lower craterlets on the western side and that of arrival of the detonative sound, observed on the evening of Jan. 18th, 1914, at the Satsumaya hotel (situated at the foot of Shiroyama Park in Kagoshima), was 17.6 sec. on the average. As the air temperature at the time in question was about 6°.5 C, for which the velocity of sound propagation in air is 336.5 m/sec., the above time interval corresponds to the path length of $336.5 \times 17.6 = 5920$ m, which is very nearly the distance of the place of observation from the lowest craterlet of the eruption fissure (No. 4) above Hakamagoshi. According to a photograph of the Sakura-jima mountain I took on the same evening from the coast of Kagoshima at the vicinity of the railway station, at about 9 p.m., this same craterlet was the only one which gave a conspicuous luminous effect on the sensitive plate, although the outbursts from the higher vents were also very beautiful to look at. It is thus evident that on the 18th of January, or one week after the commencement of the eruption, if not earlier, the principal centre of the volcanic activity on the western side was restricted to the lowest craterlet.

The outbursts from the lower eastern craterlets continued to give out detonative sounds even at the end of 1914. Thus, on Oct. 2nd, 1914, while the author was staying at Komen, an eruptive sound with some shaking effect was perceived at 10.40 p.m., the duration being 5 sec.

With respect to the eruptions from the eastern craterlets Nos. 3, 4, and 7, I have witnessed from Krokami and the islet of Moe-jima several times, on Oct. 2nd, 1914, that the emission of thin white smokes was generally accompanied by a very loud detonation, while the outbursts of black smokes caused only low sounds.

Sakura-jima Eruption of 1914 : the Craterlets on the Western Eruption Field. (F. Omori, photo.)

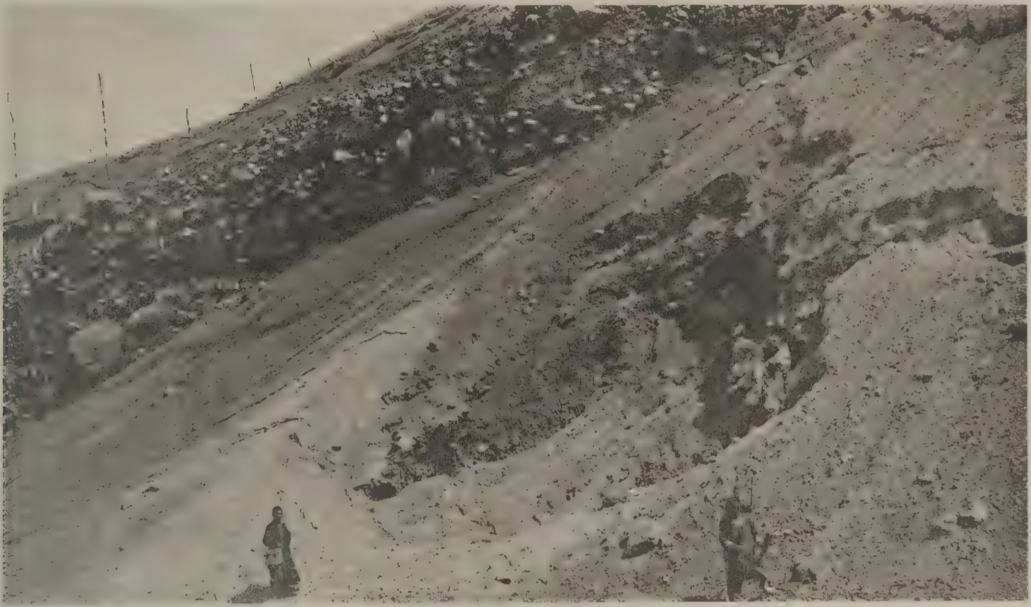


Fig. 48. A small Secondary Craterlet formed at a height of 370 m above sea-level, near the head of a valley above the village of Take. (March, 1914.)

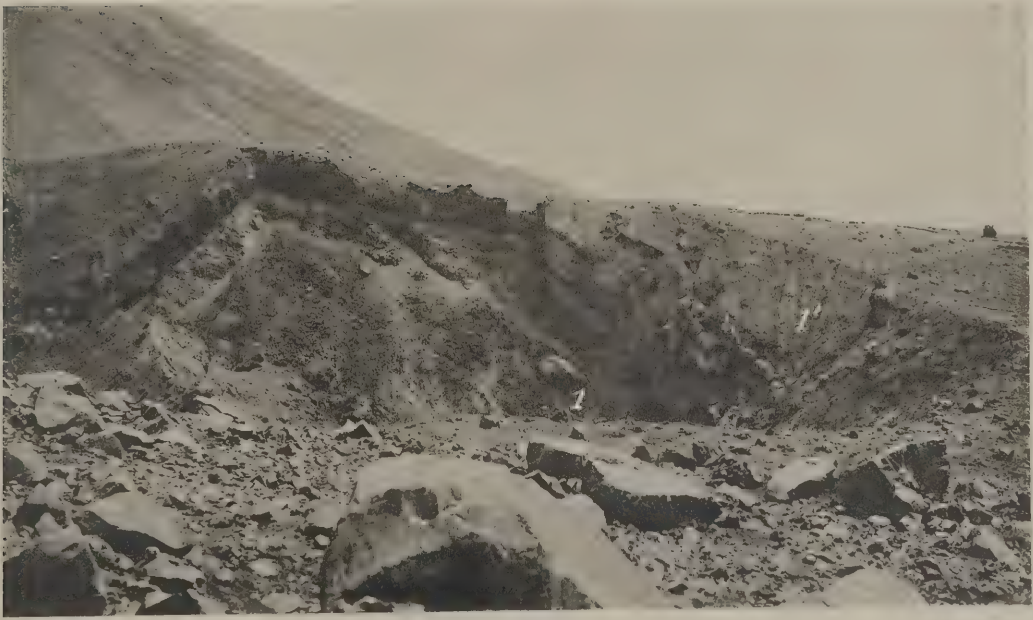


Fig. 49. Explosion Craterlet No. 1 seen from the west where the rim is lowest. The remainder of the small funnel shaped hole (1') is shown near the right hand end of the craterlet. (Sept. 1914. F. Omori, photo.)

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Sakura-jima Eruption of 1914 : W. Side Lava Source Region. (April, 1915. F. Omori, photo.)

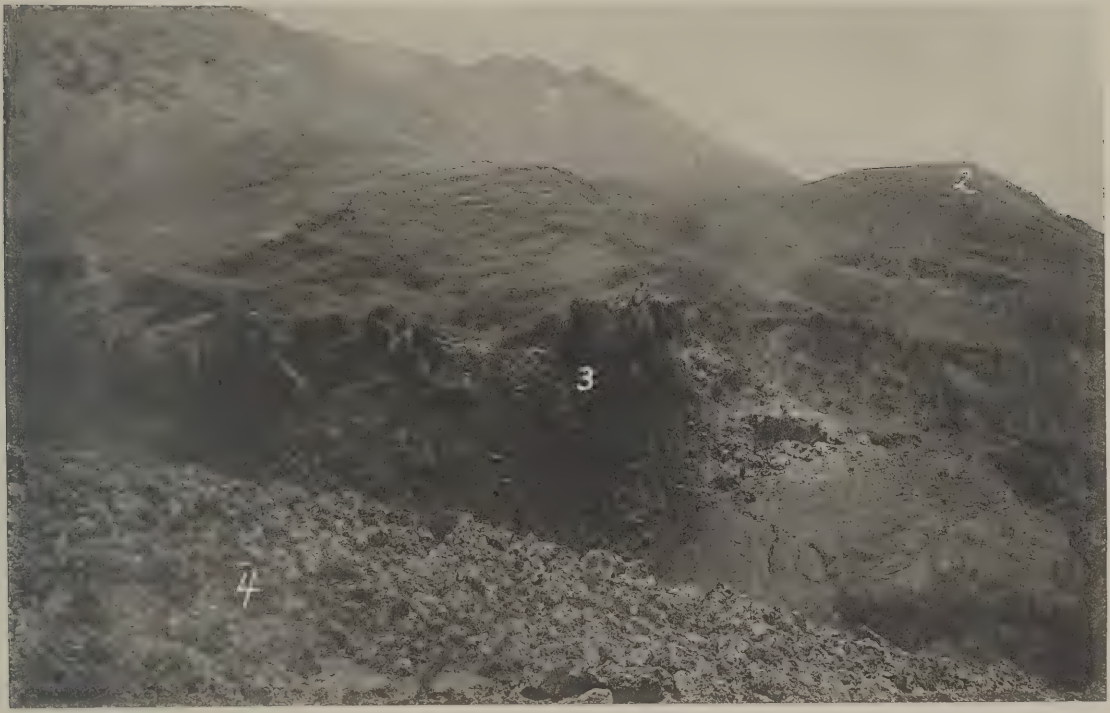

Fig. 50. View taken from the top of Yokomine Hill (4) of the disturbed area above the curved and broken lava outlet (3). Minami-dake (1) is shown on the back ground and Hikinohira (2) on the right-hand side.

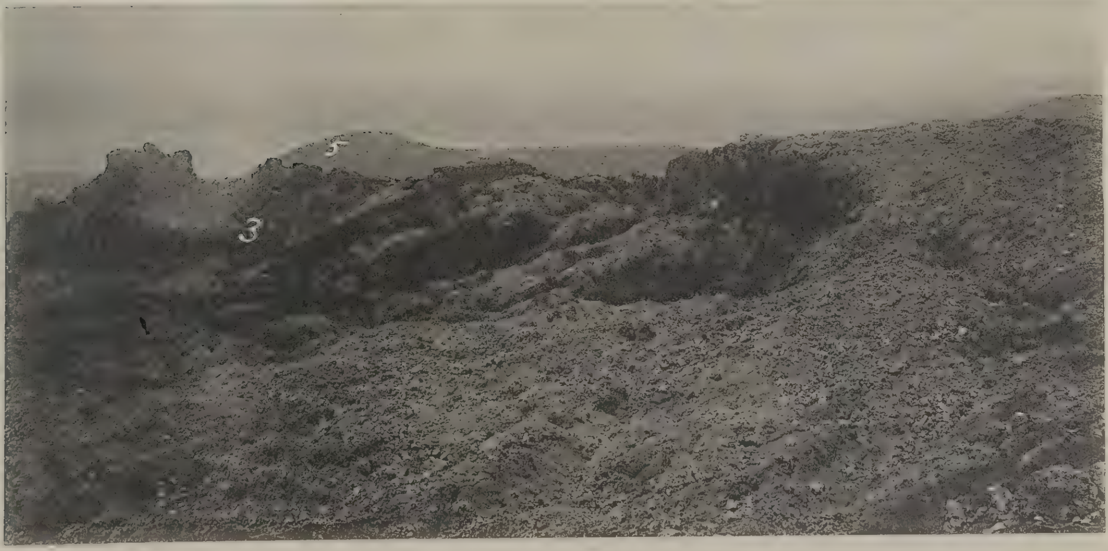

Fig. 51. Broken-up Lava Source (3), viewed from the eastern or higher slope. On the back ground is shown Yokomine Hill (5) with some smokes issuing from top.

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Sakura-jima Eruption of 1914: the W. Side Lava Outflow.

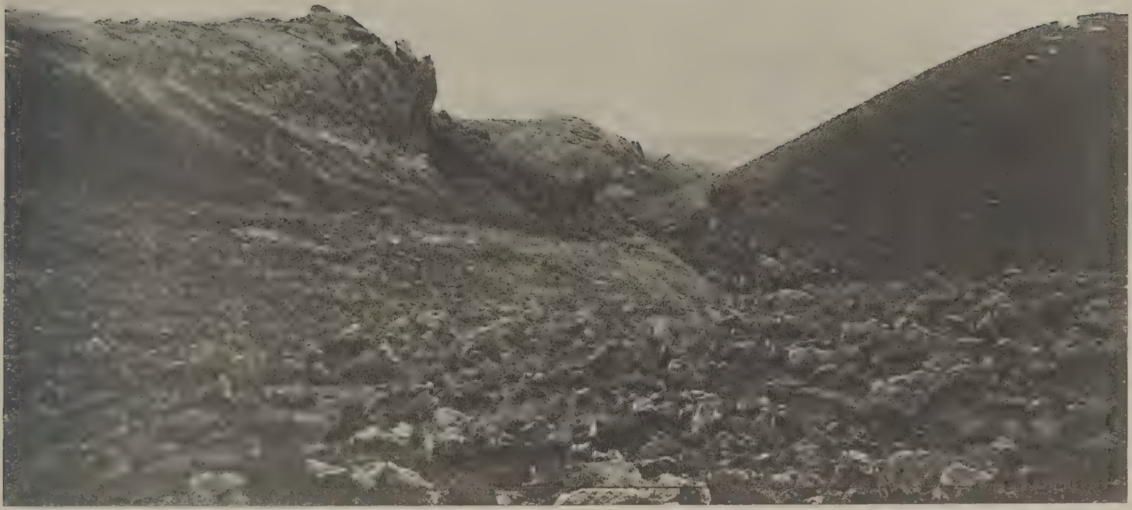

Fig. 52. Curved Lava Source (shown at the left-hand side) 400 m above sea-level, whence the downward flow took place along the S. base of Yokomine Hill shown at the right-hand side. (April, 1915. F. Omori, photo.)

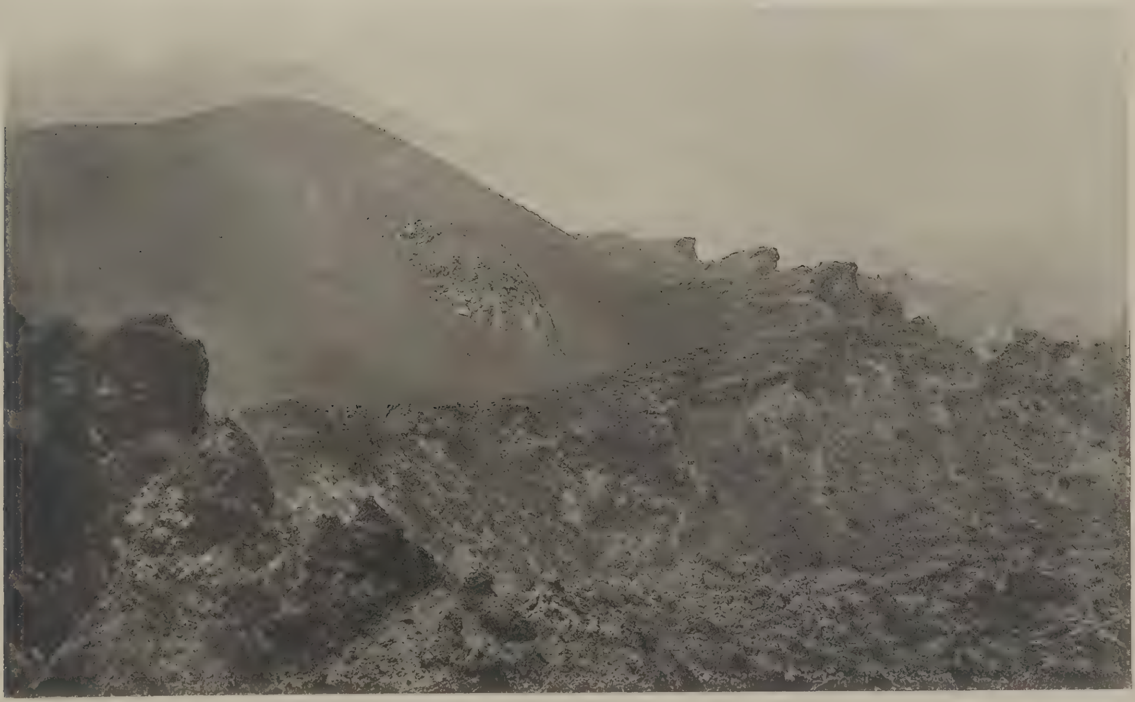

Fig. 53. Lower course of the same lava flow, showing the Depression along the middle course and the formation of Lava Terrace along the base, shown at the left-hand side. (March 22nd, 1914. K. Ueda, photo.)

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Sakura-jima Eruption of 1914 : the Western Lava Field.

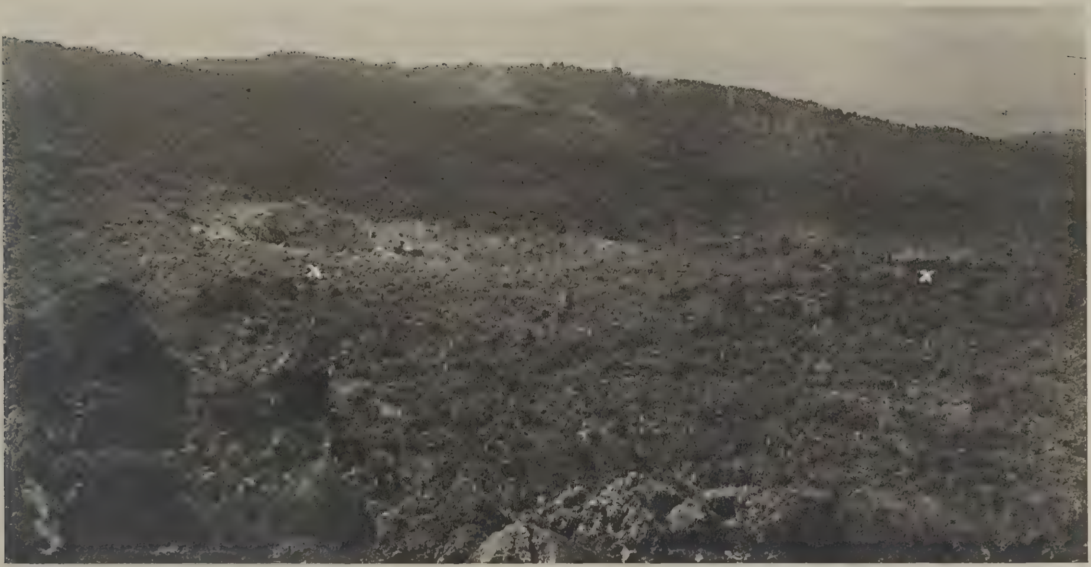

Fig. 54. Lowest Series of Craterlets (×) formed among the lava field, viewed from the N. margin at the base of Yokomine Hill. (April 1915.)

(F. Omori, photo.)

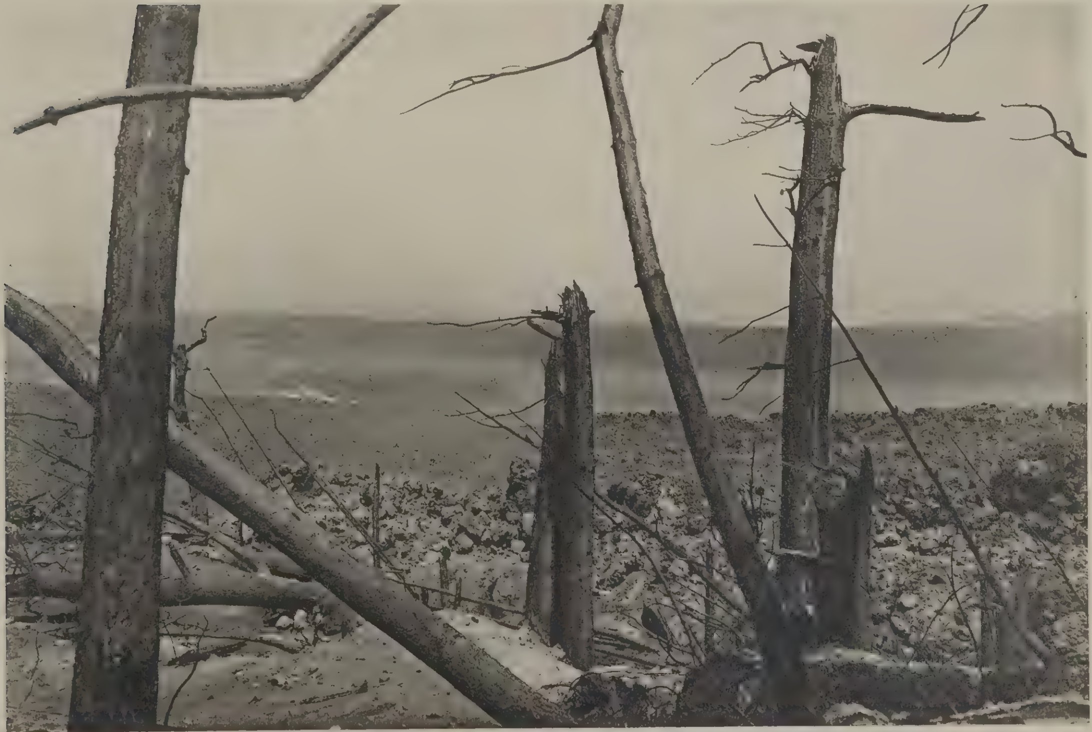

Fig. 55. Trees in the temple ground at the top of Atago-yama smashed by the impact of the lava fragments projected from the craterlets. The wooden shrine building was destroyed and swept off by the volcanic blast, leaving no trace behind. (April, 1914.)

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Sakura-jima Eruption of 1914 : the Western Lava Stream. (Jan. 19th, 1914. F. Omori, photo.)

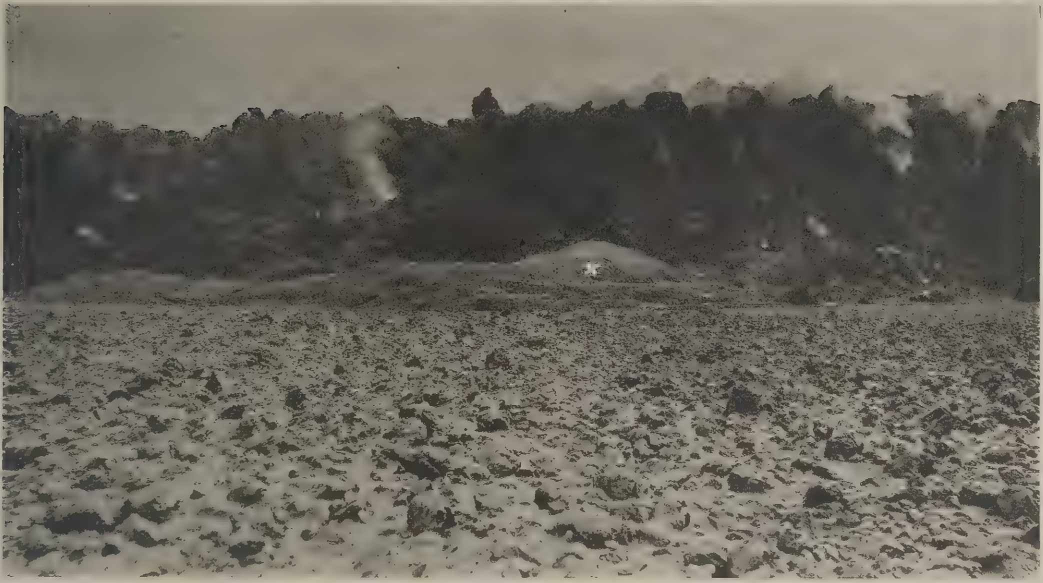

Fig. 56. The W. end of the lava flow above the village of Akobaru, showing the soil (×) forced up along the front base. In the fore-ground the pumice pieces covered the ground to a thickness of 2 feet.

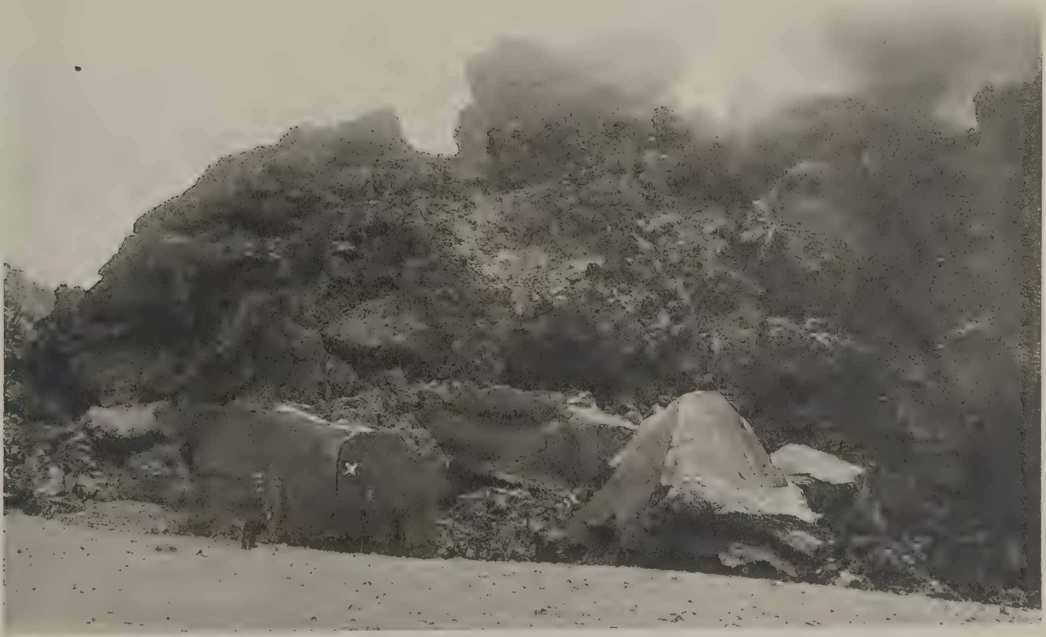

Fig. 57. The N.W. corner of the same lava flow, showing large rock pieces which fell down the sloping side. Amongst the others a large parallelopipedal block, with a crevice along an edge (×), still preserved redhot condition inside.

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Sakura jima Eruption of 1914 : the Western Lava Flow. (Jan. 19th, 1914. F. Omori, photo.)

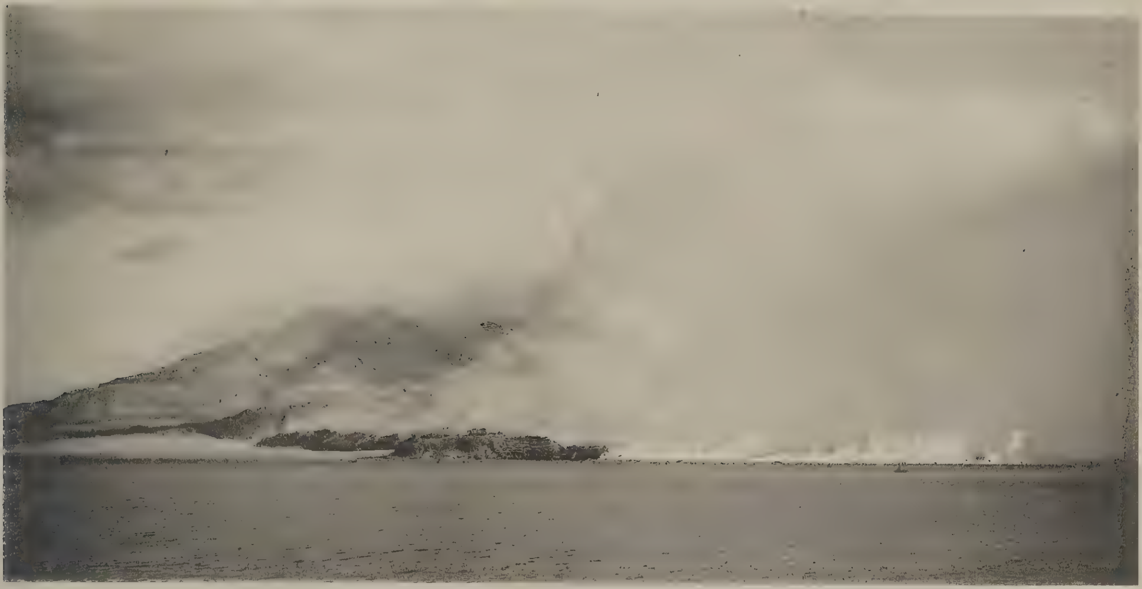

Fig. 58. View of Sakura-jima from the W., showing at the right-hand side white water vapours rising from the lava area which extended into sea.

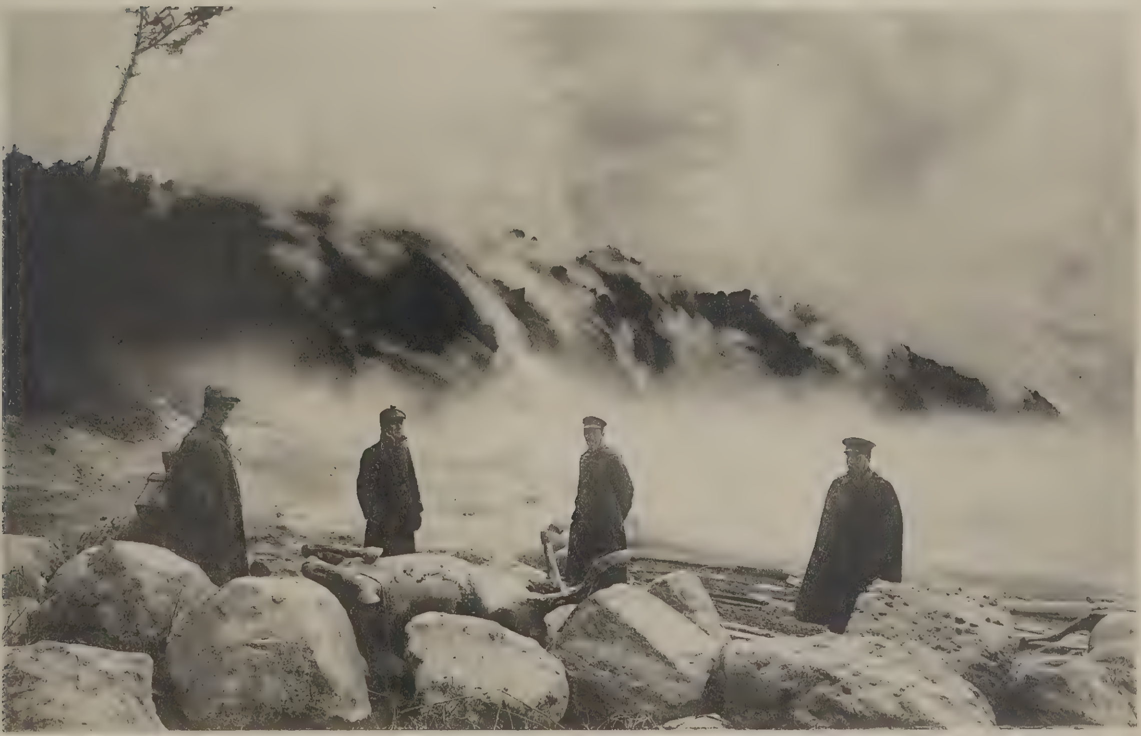

Fig. 59. Hakamagoshi Lava Stream; vapours being sent up from the neighbouring heated water surface. On the beach there were found several dead horses and great quantity of broken house timbers.

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17. Small earthquake shocks. Within a limited space at the N.W. base of the Akobaru branch lava flow to the N.E. of Hakamagoshi there were felt, at the time of my visit to Sakura-jima on Jan. 19th, 1914, a very frequent series of small tremors like that caused by the falling of a heavy weight on the ground. These were quite sharp in character, often causing people standing at the foot of the lava masses to involuntarily recede backwards. The shocks were extremely local and evidently of a very shallow origin, having been not felt on the neighbouring low hill group or in the vicinity of Hakamagoshi.

The phenomena of local earthquakes were also observed on the eastern eruption field. Thus, on April 23rd, 1915, I felt the shocks of extremely quick nature at the sloping ground to the S. of the craterlets Nos. 3 and 4, as follows :—

0. 20. 24 p.m.; duration=2 sec., with sound.

4. 15. 10 p.m.; duration=7 sec., with sound.

Again, on April 24th, 1915, an earthquake of this type was felt on the S. flank of Nabe-yama at 10.28.58 a.m. The following table gives a fragmental list of the earthquakes which I have accidentally experienced in Sakura-jima or Kagoshima on Jan. 18th, 19th, and 23rd–26th, 1914.

Table II. Observation of Local Earthquakes.

Locality.	Date (1914).	Time of Occurrence.	Remarks.
Close to the N.W. boundary of Hakamagoshi Lava Stream.	Jan. 18th.	h m s 2.33.10 p.m.	Sound and shock like that caused by the fall of a heavy body on ground.
		2.36.50	*Do.*
		2.46.50	Tremors of ground, accompanied by sounds like distant thunders, continued till 2.48.20 p.m.
		3.23.05	Same as the next one.

TABLE II. (*Continued*)

Locality.	Date (1914).	Time of Occurrence.	Remarks.
Close to the N.W. end base of Akobaru Lava Branch.	Jan. 19th.	1.39.20 p.m.	Sound followed by sharp tremors like that caused by the falling of a heavy body on ground.
		1.49.05	*Do.*
		1.52.06	Two booming sounds, with an interval of 1 second between.
		1.54.15	Same as the shock at 1.39.20 p.m.
		1.56.08	Two rumbling sounds, with ½ sec. interval.
		1.57.38	Same as the shock at 1.39.20 p.m.
		1.59.58	,,
		2.01.03	,, (faint).
		2.02.22	,, (,,).
		2.04.34	,, (,,).
		2.08.45	,, (very faint).
		2.12.37	,, (faint).
,,	,,	3.21.26 p.m.	,,
		3.23.24	,,
Kagoshima city.	,,	8.42.23 p.m.	,, Duration = 3 sec.
	Jan. 23rd.	8.49.26 a.m.	Slight horizontal shaking in radial direction.
	Jan. 24th.	5.27.00 a.m.	Slight shock, shaking windows.
	Jan. 25th.	1.02.19 a.m.	Strong booming sound, followed by sharp tremors; Duration = 5 sec.
		1.10.07 ,,	*Do.*
		4.49.34 ,,	*Do.* Motion parallel to the direction joining Sakura-jima with Kagoshima.
		4.53.24 ,,	Faint booming sound, followed by tremors.
	Jan. 26th.	5.58.49 a.m.	Strong booming sound, followed by sharp tremors; Duration = 7 sec.

18. Activity in Jan. 1914. In this and the succeeding three § § I give some notes respecting the activity of the different craterlets based on my personal observations during my four trips to Sakura-jima, undertaken in Jan. 16th–26th, April 7th–20th, and Sept. 21st to Oct. 5th, in 1914, and April 18th to May 7th, 1915. The principal outbursts from the western craterlets were brought practically to end about the 25th of Jan. 1914, or approximately in 2 weeks from the commencement of the eruption.

Jan. 16th. On the afternoon of the 4th day after the commencement of the outburst, the greatest activity on the western eruption field was shown by the No. 1 craterlet, while gray masses of dense smokes like cotton balls were also ejected from the mouth a little below. The front of the main lava stream, which had been at 10½ a.m. on the 15th about 100 m distant from the beach line to the S. of Hakamagoshi, and had reached the coast probably on the afternoon of the same day, was vigorously evaporating the sea water and sending up columns of white steam. (See figs. 58 and 127.) From time to time explosions of brownish-red smokes took place from different points of the cracked surfaces of the lava flows. A fairly active explosion vent situated some distance behind Hakamagoshi had been of this type till about noon, on the 15th.

Jan. 18th. The activity on the western side, which had been much reduced on the morning, became high from about 11.30 a.m., the detonations and smoke eruptions being again much intensified. The main lava stream was on the afternoon of the 18th already so far advanced that its front came nearly in contact with the islet of Karasu-jima, while its N. side approached to within 100 metres of the base of Hakamagoshi.

Jan. 20th. On the morning, the emission of the white steam from the advancing end of the western lava field was very much increased, due doubtless to the further advance of the latter into the sea. The front side of the lava flow was submerged to such a degree that only the upper edge remained above water. The islet of Karasu-jima was already covered up by the lava and its position could not be identified easily. Off the new lava coast of Furusato and Arimra the water was turbid and ashy green in colour, and the sea surface gave out vapours like thin fogs from the streak lines due to the currents of heated waters.

Jan. 21st. The eruption smokes ascended to the height of about 3,300 m above sea-level; in Kagoshima the detonations and shaking effects becoming again strong from about 5 p.m.

Jan. 22nd. In Kagoshima, it was again ashy and dusky, the detonations being loud.

Jan. 23rd. The western craterlets, whose eruptive energy was greatly reduced, ceased to make continuous outbursts. The two upper craterlets became extinct from this date. The white vapours rising from the lower portion of the lava area reached to the height of 300 m. In the vicinity of Krokami the thick smoke emissions caused a copious precipitation of mud rain, namely, the ashes mixed with the moisture contained in the volcanic clouds. The moist ashes were highly acidic in nature such that a bluish silk handkerchief, which I had put around my neck in order to keep off the dust, was turned reddish in colour, in consequence of the accumulation of the raining mud upon the shoulders.

At Krokami and Yokoyama the gases had no smell of sulphuretted hydrogen or sulphurous acid. There was no blackening of a silver watch even when kept close to the lava streams.

On the eastern eruption field, the "chimney," from which on the 16th the white smokes had been vigorously ejected horizontally towards the downslope, was already much reduced in activity, vapours rising diffusedly and feebly upwards. Looking from the top of the old lava moraine forming the N. boundary of the Krokami plain, there were, besides the one above mentioned, smoke issues from five other sources, respectively corresponding to the craterlets Nos. 1, 2, 3 (or 3 and 4 together), 5, and 6; the outbursts from the craterlets Nos. 3 and 6 being active and emitting red hot lava from among the black smokes.

Jan. 24th. Close to the west boundary side of the eastern lava field, which was at a distance of about $\frac{1}{3}$ km from the E. end of the village of Furusato, a strong disgustful smell of chlorine was perceived on the slope ground, from the beach up to the height of 300 m. Especially for the width of about 10 metres from the base of the side lava moraine, the ash-layer covering the ground was at places moist and had thin yellow incrustations These circumstances were not verified on the western eruption fields, except near the lava sources in the vicinity of Hikinohira.

Looking from the sea off the south coast of Sakura-jima, the eastern No. 1 craterlet was observed to issue feebly some white smokes, clearly indicating the hardened source of the lava stream which had flowed out from its lower edge. The smokes from the other eastern craterlets ascended to the height of about 3000 m above sea-level.

Jan. 25th. The western large No. 1 craterlet was perfectly quiet, only thin bluish-white smokes being feebly thrown up.

1º. Activity in April, 1914. In the beginning of April 1914, namely, 3 months after the commencement of the eruption, the outbursts, now limited to the eastern side alone, took place from the craterlets Nos. 2, 3, 4, 5, 6″, and 7. (See figs. 79 and 82.)

April 9th. The lower parts of the side and front of the eastern (Arimra) lava outflows were almost constantly crumbling down with considerable violence and loud sounds. In the ground to the east of Furusato, the smell of chlorine was excessive as in the preceding January. At 0.14.50 p.m. was witnessed from a near distance a loud detonative explosion from the eastern craterlet No. 2, when the lava fragments were thrown out like flying birds, some of these taking 8 sec. in descending from the height to which they were projected and which would approximately be about 250 m. This explosion was said to be louder than any heard at Furusato during the several preceding weeks. One of the eruptions from the craterlet No. 3 threw out lava fragments with steam tails simultaneously radiating from among the smoke masses, as is sketched in fig. 60. On the evening several faint but distinct eruption sounds were heard in Kagoshima.

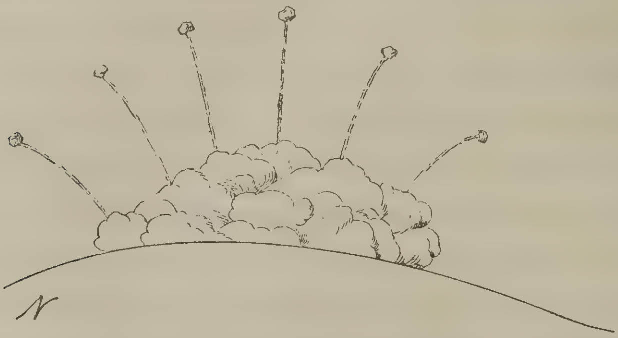


Fig. 60. A small outburst from the eastern No. 4 craterlet: projection of lava blocks trailing a tail of gas and vapour. N...Nabe-yama top.

April 10th. In Kagoshima the sky was cloudy on account of the ashes thrown out from Sakura-jima. The sounds were slight but almost incessantly heard in Kagoshima, often lightly shaking the shojis.

April 18th. In Kagoshima there was a slight precipitation of ashes, faint rumbling sounds being heard since the morning.

20. Activity in Sept. 1914. In Sept. 1914, or 8 months after the commencement of the eruption, the eastern craterlet No. 4 remained comparatively most active, the craterlets Nos. 3, 5, 6″, and 7, on the same side exhibiting also occasional outbursts. (See figs. 86 and 87.)

The coast side or the advancing front of the lava field in the Arimra district crumbled down with rustling noise from time to time in much the same manner as in the preceding April; the black rock masses here and there visible being the new lavas forced out of the cracks of the older flows.

Sept. 22nd. In Kagoshima, between 8 and 9 p.m., low rumbling sounds were heard twice. During the night, the eruptions on the eastern side rendered the sky slightly luminous so that the outline of the mountain seen from the west was just discernible.

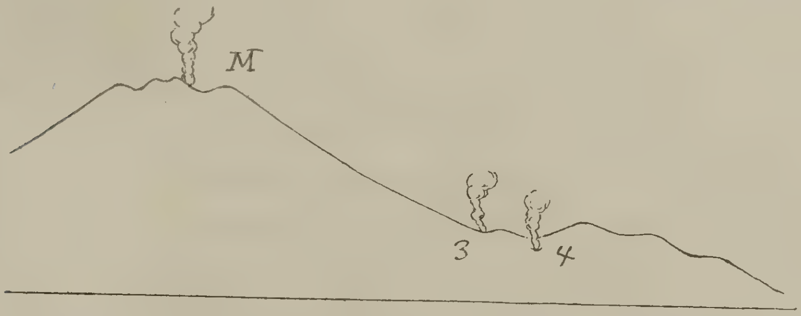


Fig. 61. Outline of Sakura-jima seen from the South, on Sept. 24th, 1914, indicating smoke issues from Minami-dake (M), and the eastern craterlets Nos. 3 and 4, when the latter remained quiet.

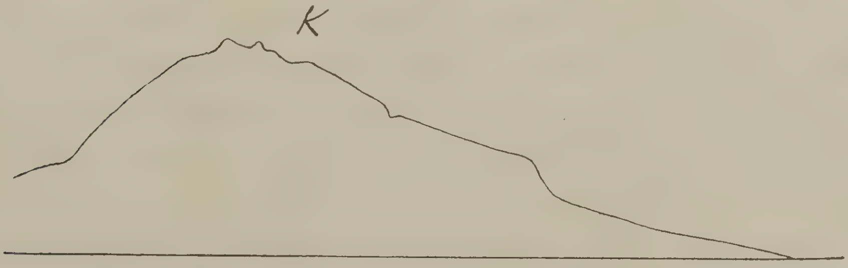


Fig. 62. Outline of Sakura-jima seen from the North. (K... Kita-dake.)

Sept. 23rd. While the author was standing on the top of Hikinohira, rushing sounds were heard at 1.23.20–24.10 p.m., and also at 1.31.20–31.40 p.m. The smell of sulphurous acid and other gases became much weaker than in the preceding April.

Sept. 24th. It was cloudy, perfectly calm, and sultry. While looking toward Sakura-jima from the upper story of the hotel Nagamine, in the town of Tarumizu, I observed at 5.45 p.m. a moderate-sized gray smoke-column rising from the craterlet No. 7 at the S.E. base of Nabe-yama, situated at the height of 140 m above sea-level; the booming sound, of 3 sec. duration, was fairly loud, yet caused no shaking of the shojis (paper-covered sliding doors in Japanese houses). By the time when the sound was heard at Tarumizu, which ought to be about 26 sec. after the moment of occurrence of the outburst at the origin as stated below, the smokes rose to an elevation equivalent to the four-fifths of the mountain height, namely, some 860 m. Hence the average velocity of the smoke ascent in question was approximately 28 metres per sec. From Tarumizu dull red fires began to be seen at 6.23 p.m. about the craterlets Nos. 3 and 4, and during the evening the eruptions from these were like gigantic fireworks. The craterlet No. 4 (lower) was very active, while the craterlet No. 3 (upper) was feeble and often became completely dark. The rushing sound caused by the air disturbances reached the place I was sitting on the average 26.4 sec. after the first moment of appearance of the luminous outburst at the craterlet No. 4. As the distance to the latter was 9450 m, the mean propagation velocity of the sounds comes out to be 358 m/sec., the air temperature at the time being about 24° C.

Sept. 25th. The weather was rainy and calm. Looking from Tarumizu, the craterlet No. 3 was seen from about 11 a.m. to emit up continuously white smokes with rushing sounds, while the craterlet No. 3 was very inactive and at times became completely quiet. The craterlet No. 7, situated at the S.E. base of Nabe-yama, made an outburst at 8.52 a.m. which caused a loud booming sound, 2 sec. in duration. An explosion from the same craterlet at about 8 a.m. had been stronger, and caused a shock to the shojis, giving out a smoke column of the diameter equal to that of the top of Nabe-yama. At about 4½ p.m. took place an abundant smoke emission from the craterlet No. 5, situated in the western branch of the Nabe-yama eruption crack, lasting for ½ hour.

Sept. 26th. Occasional explosions took place from the two craterlets in the lower part of the eastern branch of the Nabe-yama Eruption Crack, from whose end a black lava stream was still flowing out. Seen during the night the stronger eruptions from the No. 4 craterlet sent up the red hot lava pieces at least through the height of 350 m, the horizontal radius of projection being about ⅓ km.

Sept. 27th. The day was fine and quiet. Ascending from the Yunohama (or Yubama) beach along the W. boundary of the lava area, it was noticed that the bad smell of chlorine was much less than in the preceding April. Reaching at 9.40 a.m. a level nearly equal in altitude to the tob of Nabe-yama, where we were 800 m distant from the craterlet No. 3, it was observed that the latter was often making puffing noises like those of a locomotive ascending a slope, whose frequency was as follows :—

35 puffs in 25 sec.
50 ,, 35 } ......*Mean*, 1 puff in 0.76 sec.
73 ,, 60

The mean interval between the successive puffs was thus 0.76 sec. When the smokes were steadily issuing from the craterlet in question, it caused no puffing sound. While the author was standing at the beach of Yunohama, at 3.09 and 3.45 p.m. two strong booming sounds were heard, which were perceived also at Tarumizu as detonations with some shaking effects. During the evening it was observed from Tarumizu that the craterlet No. 3 made no outburst, while the craterlet No. 4 was less active than in the preceding night.

Sept. 28th. The weather was clear and perfectly calm. At 8.24 and 8.25 a.m., I observed from Tarumizu two strong fine smoke eruptions from the craterlet No. 4, accompanied by faint sound. The time required by the smoke column, which ascended vertically, in reaching the height equal to that of the Sakurajima mountain was 46 sec. in the first, and 48 sec. in the second case. The average velocity of the smoke ascent was thus approximately 19 m/sec.

Sept. 30th. In Kagoshima, a booming sound was heard at 9.53 p.m.

Oct. 2nd. While going on a small boat from Komen to Krokami, and again coming back along the N.E. coast of Sakurajima, I have observed eruptions from the craterlet No. 7 at the E. base of Nabe-yama, which took place as follows:—8.20 a.m. (twice); 8.29 a.m.; 2.18 p.m.; 2.41 p.m.

21. Condition in April and May, 1915. On April 22nd, 1915, the eastern volcanic vents were found completely quiet, except that there was only a slight issue of smokes from the upper part of the inside wall of the No. 3 craterlet, while the wall of the No. 4 craterlet almost constantly crumbled down, causing an uprush of brownish dusts. The air was highly flickering below the latter craterlet, namely, just above the head of the black lava source situated at the lower neighbourhood. From the small eruptive hole lying between the craterlets Nos. 1 and 2, and to the S. of the Canal Zone between these two, there was a copious issue of gases with a strong pungent smell.

Small outbursts on May 5, 1915. For the first time during my 4th visit to Sakura-jima, since April 18th (1915), there occurred on the 5th of May a series of small non-detonative outbursts from the No. 4 craterlet, which I have observed from a small boat at the vicinity of Krokami, the time of appearance above the Nabe-yama top of the successive smoke masses being as follows :—

Time of occurrence.	Interval.	Time of occurrence.	Interval.
10.29.50 a.m.		10.41.12 a.m.	
	... ... 55 sec.		... ... 68* sec.
30.45		42.20	
	 35		 50
31.20		43.10	
	 40		 18
32.00		(Strong) 43.28	
	... ...160*		 32
34.40		44.00	
	 43		... ... 95*
35.23		45.35	
	 37		 67
36.00		46.42	
	 35		 38
36.35		47.20	
	 53		 60
37.28		48.20	
	... ... 77*		 45
38.45		49.05	
	 60		 27
39.45		49.32	
	 30		 43
40.15		50.15	
	 20		... ... 70*
40.35		51.25	
	 37		 65

Time of occurrence.	Interval.
10.52.30 a.m.	
	... ... 35 sec.
53.05	
	 47
53.52	
	 43
54.35	
	 50
55.25	
	... ...108*
57.13	
(A pause.)	

Time of occurrence.	Interval.
11.08.45 a.m.	
	... ...103 sec.
10.28	
(A pause.)	
16.50	
(A pause.)	
11.55.20 a.m.	
(A pause.)	
0.02.40 p.m.	

Thus the outbursts, which occurred frequently for 27 min. 23 sec., between 10.29.50 (commencement) and 10.57.13 a.m. at successive intervals of 18 to 160 sec., became thereafter much reduced in activity and were separated by long pauses of 6 to 38½ min., till the final termination at 0.02.40 p.m. The time interval between the successive moments of the appearance of the smoke masses, which reached a maximum length after some half a dozen repetitions (marked with an *asterisk* in the preceding list), varied between 18 and 77 sec., with the mean of 46 sec., being longer, namely, 95 to 160 sec., only in 4 cases.

The smokes, which were not properly dark, but light red in colour in consequence of the mixture of the red dusts falling from the craterlet's side, ascended to the maximum height of only about 700 m above sea-level; the explosions being strong enough just to shoot the "cauliflower" clouds above the Nabe-yama top.

22. Summary. The order of succession of the activity of the different eastern craterlets was in short as follows:—

No. 1'. The "chimney" was probably the earliest in the manifestation of activity. The steady issue of the white smokes, which was still maintained on Jan. 16th, 1914, has come to an end a few days later. On Jan. 23rd, 1914, the smokes were being given out very feebly.

No. 1. This highest explosion craterlet was the first on the E. side to make the real outburst, its activity continuing for 4 or 5 days. On Jan. 23rd, 1914 it was giving forth smokes feebly.

No. 2. The double craterlet was making strong eruptions even in March-April, 1914. The activity was found completely reduced in Sept.-Oct. of the same year.

Nos. 3 and 4. When seen on Jan. 23rd, 1914, the No. 3 craterlet was the most active among the different craterlets. In the following March-April, the two craterlets Nos. 3 and 4 were still making very energetic outbursts almost continuously. In Sept. and Oct. of the same year, these made explosions from time to time, the No. 4 being then the more active one.

No. 5. On Jan. 23rd, 1914, the No. 5 craterlet was found to be one of the most active craterlets. It continued to make occasional eruptions till Sept. and Oct., 1914.

No. 6. This seems to have displayed its activity only during the earlier days of the eruption.

Nos. 6″ and 7. These two craterlets, one of which already existed, like those above mentioned, at the time of my first visit to Sakura-jima on Jan. 16th, 1914, preserved its activity together with the craterlets Nos. 3 and 4 till the very last epoch in the course of the present eruption, occasional slight explosions occurring even in March and April, 1915. The lava flow from the two craterlets Nos. 4 and 7 probably took place more or less till the middle of 1914.

Chapter III. Lava Outflows.

23. Rate of lava flow. The lava of the recent Sakura-jima eruption, like those of the 1779 and 1468–76 outbursts, had a low degree of fluidity and became quickly coated with crust broken up into angular blocks, being in this respect quite similar to the Temmei (1783) lavas of Asama-yama. (See figs. 56, 57, 59, 78, 89, 103, and 128.) On the western eruption field, the lava began to flow out probably at about 8 p.m. on the 13th of January, 1914, and has run down a slope distance of about 2.7 km in the subsequent 11 hours, till the advancing front of the stream was within about 500 m from the coast at about 7 a.m. on the next morning. Then, the lava reached the coast in the morning of the 16th, advancing thence into the shallow Kagoshima strait, till it covered a distance of 600 m and reached the islet of Karasu-jima at about noon, on the 18th. On the morning of the 25th of the same month the lava front was found to have advanced a further distance of about 400 m. The approximate average velocities of the lava progress during these different epochs were as follows :—

(Jan. 1914.)		Mean epoch.
13th, 8 p.m.—14th, 7 a.m.	Velocity = 245.4 m/h.	(14th, $1\frac{1}{2}$ a.m.)
14th, 7 a.m.—18th, noon.	,, = 10.9 ,,	(16th, $9\frac{1}{2}$ a.m.)
18th, noon—25th, noon...	,, = 2.4 ,,	(22nd, 0 a.m.)

The increase with time of the distance travelled by, and the decrease in the average frontal velocity of, the lava stream is illustrated in fig. 63; the velocity decrease, which was from 245.4 to 10.9 metre/h in the course of the $2\frac{1}{3}$ days from the 14th to the 16th, being approximately in the relation of a logarithmic curve. It may be remarked that on Jan. 22nd, 1914, the velocity of the north *side* of the lava stream flowing to the south of Hakamagoshi was found to be about 1 foot per hour, which is much smaller than that of the frontal motion corresponding to the same date, namely, of 2.4 metre/hour.

On the eastern eruption field, the lava flowed down on the 4th of March, 1914, already to a submarine point 3 km distant from the original coast of Arimra, giving the average velocity of 4 m/h during the time interval concerned. In June next, when the soundings were taken by the Imperial Navy, the lava front was found to have advanced a further distance of about 1 km, giving the average velocity of 0.28 m/h. As may be seen from the diagram (fig. 63), this flow velocity was several times higher than

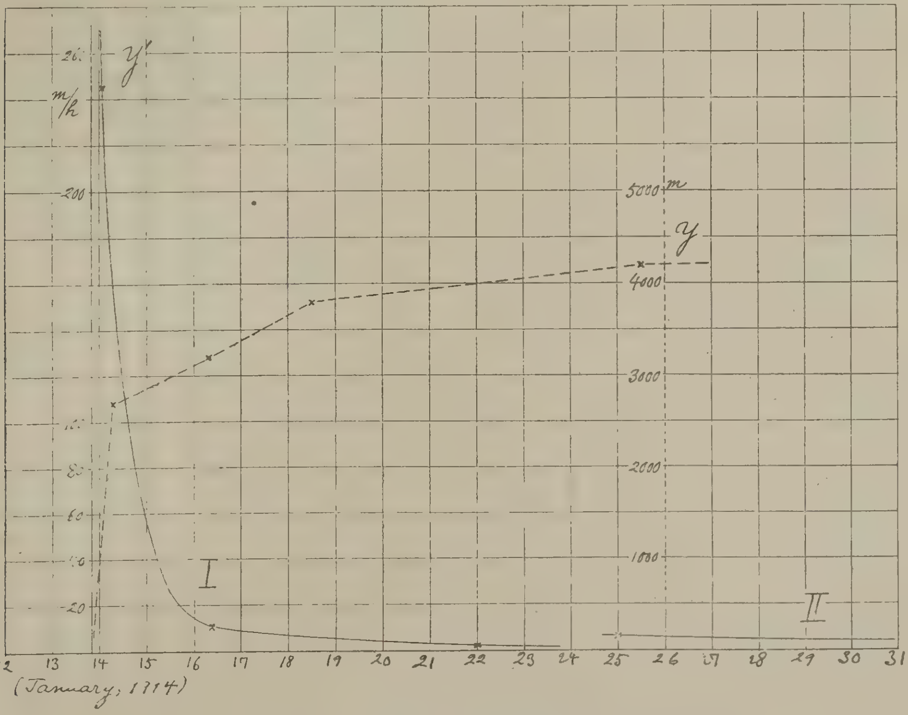


Fig. 63. Progress of the Western Lava Stream.
I : y' = Mean transit velocity of the lava stream in metre/hour.
y = Extension (length) of the lava stream, in metres.
[II relates to the mean velocity of the eastern lava flow.]

the corresponding value for the west side field, due doubtless to the difference in the volume of the moving lavas and the sea-depth off the two different coasts of Sakura-jima.

24. Condition in 1914 and 1915. The western lava field attained nearly its full extension in the course of one month or so, owing to the early cessation of the outbursts from the western craterlets. The eastern lava field, whose submerged portion reached approximately the maximum elongation also in a comparatively short time (§ 23), continued to exhibit till the beginning of 1915 signs of activity consequent to its forward displacement; the terminal front, or the new sea coast, giving rise to innumerable vapour issues and to very frequent occurrences of small avalanches of the hot lava masses. (See Chapter VIII.)

Jan. 19th, 1914; *Western Lava Field.* The sides of the lava streams were constantly crumbling down with loud rustling noises, and caused each time an uprush of brownish dusts; during the night red glares being seen at several points of the lava fields. The distance between the S. base of Hakamagoshi and the N. side of the main lava stream, which had been about 120 ft. at 2 p.m. on the previous day, was reduced to about 12 ft. at 11$\frac{3}{4}$ a.m. on the 19th; this space having again been covered up in the course of the next 1 hour, due partly to the shaking down of the lava masses and partly to the lateral extension consequent to the settling down of the lava along the central portion of the stream. The velocity of the downward progress of the lava stream *side* was then about 1 ft. per hour. At the end foot of the N.W. branch stream of the western lava area, where it emerges from the valley along the hill groups above Akobaru, there were several large rock pieces which had crumbled down the slope (fig. 57). One of these was a massive parallelopipedal block measuring 9×9×15 ft., which was cleft at a corner to the width of about 4 inches. The exterior side of the block was still too hot to be conveniently touched with hand, and had probably a temperature of 60° or 70° C. The inside of the block was, however, still in a semi-molten condition, and was red-hot to within 1 metre from the edge, representing approximately the rate of cooling of the surface lava mass during the 5 days since the morning of the 14th (Jan. 1914), when the molten stream had reached the place in question.

The nearest distance between the beach line of Akobaru and the outermost base of the branch lava flow under consideration was approximately 221 m on April 18th, 1914, at the low-tide time, while it was found to be 216 m on Sept. 23rd of the same year, at a full-tide time. It thus follows that the advance of the Akobaru lava stream came to a standstill some time before the middle of April, in 1914, or within 3 months after the commencement of the eruption.

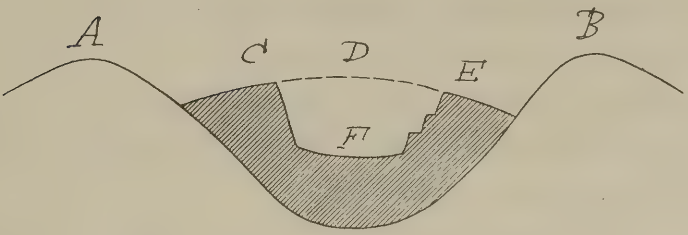
Sept. 27th, 1914 ; *Eastern Lava Field.* It was noticed that the side and front of the lava flows crumbled down from time to to time. The escape of the white fumes from the side moraine of the lava at Yunohama, generally from the middle and lower portions, was limited to the distance of about 300 m from the coast. The distance between the W. boundary of the lava field and the E. limit of the village of Yunohama was 342 m.

April 1915. 19*th* : when it was raining, thin smoke columns were feebly rising from the land lava area to the N.E. of Hakamagoshi, while white vapours were abundantly given out from the portion projecting into the sea to the S. of the latter platform. 21*st* : On the Arimra side, much white vapours were thrown up from several points in the front portions, sometimes accompanied by rustling noises. (See also Chapt. VIII.) There was now no crumbling down of the side moraine of the lava flow at the coast of Yunohama. During an ascent to Nabe-yama on the 22nd, it was noticed that there was at its S.E. foot a small area in which the trees were dead but remained standing ; this being no other than the space left uncovered by the lava streams which flowed down from the craterlets Nos. 4, 4′, and 5 on the one hand and from the craterlets Nos. 6 and 7 on the other.

25. Lava cascades. Lava cascades were formed by the molten rock which flowed into the crater or the central hollow space of Nabe-yama and along the ravine between the N. side of the latter and the S. side of the adjacent Gongen-yama (figs. 84, 85, and 83). Unlike the ordinary lava streams of Sakura-jima these are compact, giving approximately an even top plane, and not having rugged broken up surface, due doubtless to an immediate proximity to their source, probably the eastern No. 2 double craterlet, and to their formation while the lavas maintained a very high degree of fluidity. In the Nabe-yama crater, the inflow of the lavas took place principally in two successive stages, the lower edge of the cascade being arranged in two steps.

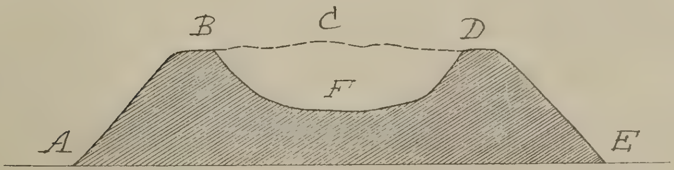
26. Marginal terrace and side moraine. A lava stream of the Sakura-jima type, which continues its progress for a considerable length of time, although with a rapidly decreasing speed, is quickly coated with a layer of solidified rocks. As, however, the inner mass is hot and flows on, there will be soon left a vacant space beneath the surface crust, causing the latter to settle down through a more or less considerable vertical distance. If the lava outflow takes place along a valley, as in fig. 64, there thus results a sort of horizontal or inclined terrace on each side of the central depression CFE. The dislocation boundary at C and E may be very steep or may form a gradual slope. Thus at a point on the S. slope of the

Fig. 64.



Diagrammatic Section of a Lava Stream flowing down a Valley.
CDE......Initial surface.
CFE......Depressed surface.

Fig. 65.



Diagrammatic Section of a Lava Stream flowing down an Inclined Plane.
BCD......Initial top surface.
BFD......Depressed top surface.

elongated 360 m hill above Akobaru, the terrace was 90 m in width and its rough surface sloped down at an inclination of about 17°, while the lower cliff was nearly perpendicular and about 45 m in depth. (See fig. 53.) On the opposite side, at the N. slope of Atago-yama above Akamizu, the dislocation took place in three successive steps, the upper two of which together had a depth of 20 m. If the lava stream expands over a flat ground, the initial surface form BCD of the outflow (fig. 65) will be changed by the middle subsidence into BFD, leaving on each side a well defined ridge moraine of rough rocks. The formation of the moraine may be marginal or terminal and is to be met with almost always in the lower course of a Sakura-jima lava stream. At Yunohama, on the S.E. coast of the island, the western marginal moraine had a vertical height of about 80 m with a side inclination of $35^\circ\frac{1}{2}$. (See also § 27.)

27. Height and slope inclination of lava stream. (See figs. 89 and 128.) The heights and the slope angles of the marginal and terminal sides of the new Sakura-jima lava streams, determined at different places from measurements with a clinometer and a prismatic compass, are as follows.

Place.	Terminal "Moraine."		Marginal "Moraine."	
	Slope Angle.	Height.	Slope Angle.	Height.
Yunohama, at sea-coast.	—	—$^{\mathrm{m}}$	35.°5	80$^{\mathrm{m}}$
Seto Strait Lava opposite Ushine.	30° apprx.	75	—	57
Above Nojiri.	39.°0	—	39.°5	—
"	41.°0	60 apprx.	—	—
Akamizu, on shore.	—	—	41.°0	19
" , in sea.	—	—	32.°5	17
Bummei Lava, near Nojiri.*	35.°5	37	33.°5	—

(*) This refers to old lava outflow.

From the above list the terminal and marginal slope angles seem to be practically alike, both varying from a little above 30° up to 41°, giving the mean value of 36°. The slope inclinations of the side cone Hikinohira and of the upper part of Minami-dake (South Peak) are of a practically equal amount, being from about 33° to 37°, as shown below.

Place.	Slope Angle.*
Kwannon-zaki. (Terminal.)	36°
Tatsu-zaki, near Furusato. (Terminal.)	34°
Minami-dake (S. Peak), W. slope, near the top.	33°
" , E. slope, "	34°
Hikinohira (S.W. slope).	37°
Nabe-yama (N. slope).	39°

(*) Measured from the new Military Survey 1/25.000 map of Sakura-jima.

The slope angle of the old lava outflows of Bummei period (1468–76) and of much earlier dates such as those forming the promontories of Kwannon-zaki and Tatsu-zaki is also equal to 34° to 36°. The very steepness of the slope (=39°) of Nabe-yama, which is originally made up entirely of pumice, might have been caused by the strong denuding influence of rain.

The formation of the terminal and marginal sides of a lava outflow is in the first place due to the greater mobility of its inner and lower positions ; the top surface layer, hardened into crust, tending to lag behind. The final amount of inclination of the slope, however, must be equal to the angle of repose of the volcanic material determined by the coefficient of friction of the latter. It is probably owing to this circumstance that the inclination angle of a lava flow is approximately equal at the terminal and side slopes.

According to the above given table the maximum height or thickness of the new Sakura-jima land lava outflows along the side and terminal slopes was 80 m. The submarine lava outflow off the south-eastern coast of the island was much greater, reaching the amount of 123 m (§ 31). Again the lava accumulation in Seto Strait attained the total vertical thickness of about 180 m (Chapter IV).

28. Soil forced up by advancing lava flow. At the front base of the Akobaru branch lava stream the soil was forced up to stepwise terraces with the maximum vertical height of about 7 metres. (See the photograph, fig. 56.) This is evidently the result of the advancing lava mass having been more or less abruptly brought to a stoppage, which exerted a heavy pressure to the underlying sandy or pumiceous slope soil with a small inclination angle (fig. 66). At the rest of the western eruption field, a similar effect was not observed, either having been masked by the layer of fallen pumice

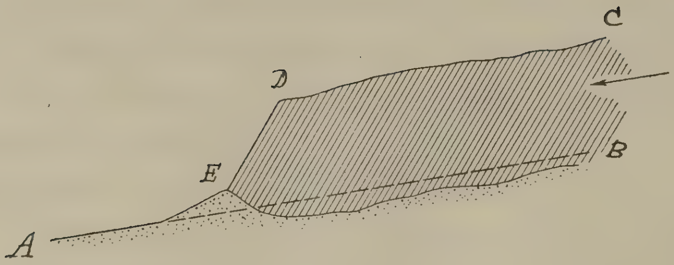


Fig. 66. Hard lava stream (DB) causing the soil (E) in front to be forced up.

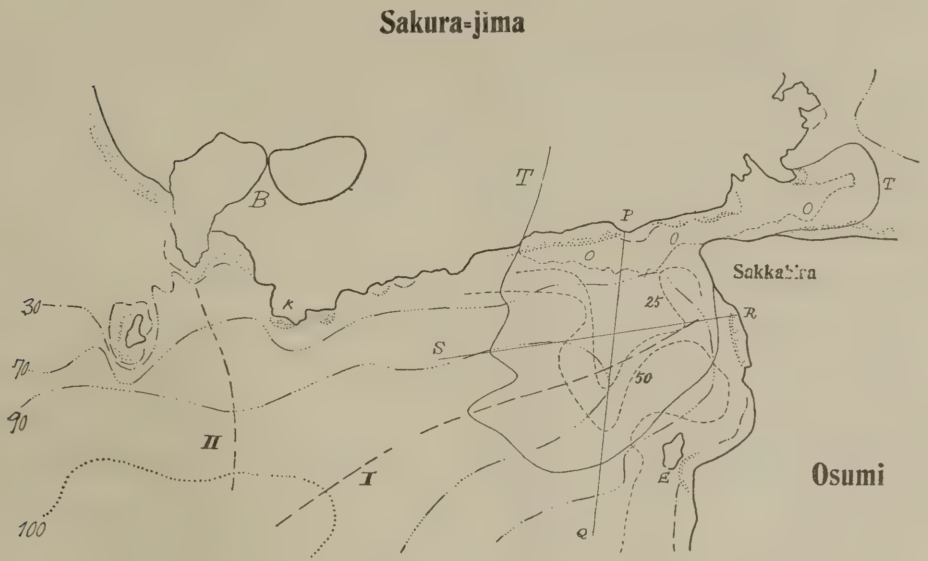
and ash or having been not produced on account of an easy downflow. Again, at Krokami the lava flow along the nearly level E. base of Nabe-yama was not accompanied by the soil raising.

29. Submarine lava flow and new-islet. According to the report from the Tarumizu police office under the date of March 6th, 1914, vapours had been emitted two days previously from under the sea at three places between Eno-shima and Sakura-jima, and the water depth, originally 70 to 80 fathoms, had been reduced to 40 to 62 fathoms. It thus seems that the eastern side lava stream flowed down into the water and reached, already on the 4th of March, 1914, a submarine distance of some 3 km from the former coast line.

In the photograph (fig. 81) taken from Tarumizu on Feb. 24th, 1914, there is indicated a flat lava islet, which thus had been formed prior to the date here mentioned, and which is the same as that described in Chapter V under the name of Arimra-jima.

30. Note on the form of lava outflow. The outflow of lava takes place of course essentially in the form of stream lines along valleys or lowest portions of mountain sides or bases, both above and below the surface of sea. The form of a new lava promontory is thus determined by the contour of the adjacent sea-bottom. Thus, in

Fig. 67. Map showing the Water Depth off the S. Coast of Sakura-jima and the Dependence of the Direction of New Lava Promontories on the Contour of Sea Bottom.



{B......Lava flow of Bummei (1475-1476).
{TT ... „ Taisho (1914), partly submerged.
{30 ; 70 ; 90 ; 100......Lines of depths respectively of 30 ; 70 ; 90 ; and 100 fathoms, *before* the Eruption of 1914.
{25 ; 50......Lines of equal depths respectively of 25 and 50 fathoms, *after* the Eruption of 1914.
{00......New lava coast in June 1914.
I, II......Zones normal to the submarine contour lines.
k......Kwannon-zaki. E......Eno-shima.

the case of the recent lava outflow on the eastern side, the main extension of the submerged portion is very nearly at right angles to the series of the curves of equal depth of 70–90 fathoms, descending and converging to the trough zone I, or the deepest portion in the vicinity (fig. 67). Again, the direction of the Moe-zaki, or "Burning cape," formed during the eruption of Bummei period (§ 8, in the preceding Number of the Bulletin) at the S.W. extremity of Sakura-jima, B in fig. 67, is deflected from the course of the same lava flow on land, having been bent towards the south-east where the sea is much deeper than on the other side. In the recent eruption, the western lava flow was naturally divided into two courses at the obstacle presented by the islet of Karasu-jima, which itself was also buried under the molten mass.

31. Submarine extension of the eastern lava outflow. In fig. 67 are indicated the lines of equal water depth off the S. coast of Sakura-jima before the eruption, as well as those drawn according to the results of the new soundings undertaken by the Admiralty in June 1914. It will be observed that after the eruption the line of 25-fathom depth stretched from the former 103 m hill (P in fig. 67) on the original coast between the villages of Seto and Arimra towards south a little west for the distance of about 1600 m from the new margin. The line of 50-fathom depth is situated generally not much distant from the above-mentioned depth line. In the following table I give a comparison of the water depths before and after the eruption at different points along the nearly north-south line PQ, approximately forming the axis of the greatest submarine lava accumulation, and also along a line RS about 1500 m distant from the former island coast and situated nearly in the east-west direction (fig. 67).

Table III. Water Depth off the S.E. Coast of Sakura-jima before and after* the Eruption of 1914.

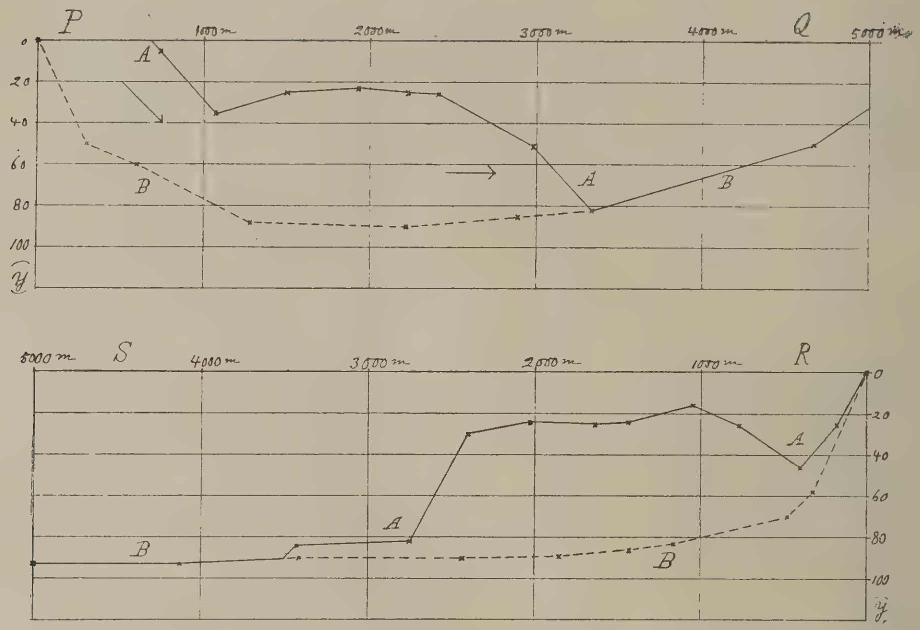
Along the N.-S. Line PQ.			Along the E.-W. Line RS.		
Distance from the coast of Sakura-Jima.	Water Depth.		Distance from the coast of Sakura jima.	Water Depth.	
	Before.	After.		Before.	After.
300^{m}	50 fathoms.	(Filled up.)	185^{m}	— fathoms.	25 fathoms.
600	60	(*Do.*)	323	58	—
740	—	5 fathoms.	402	—	46
1070	—	35	480	70	—
1280	88	—	770	—	25
1500	—	25	1050	—	16
1930	—	25	1160	83	—

TABLE III. *(Continued.)*

Along the N.-S. Line PQ.			Along the E.-W. Line RS.		
Distance from the coast of Sakura-jima.	Water Depth.		Distance from the coast of Sakura-jima.	Water Depth.	
	Before.	After.		Before.	After.
2220$^{\mathrm{m}}$	90 fathoms.	— fathoms.	1430$^{\mathrm{m}}$	86 fathoms,	— fathoms.
2230	—	25	1440	—	24
2410	—	26	1640	—	25
2890	85	—	1850	89	—
2980	—	51	2030	—	24
3330	82	82	2400	—	30
4660	50	—	2430	90	—
5030	32	—	2750	—	82
			3420	90	—
			3430	—	84
			4130	93	—
			5250	—	93

(*) In June 1914.

As will be seen from the graphical illustrations in fig. 68, the submarine lava accumulation along the N.-S. line PQ was great for the extension of 3000 m from the former S. coast of Sakura-jima. The maximum thickness of the lava layer was about 67 fathoms or 123 m, such that the depth was reduced from 90 to only 23 fathoms. Again, along the E.-W. line RS the submerged lava layer had a thickness not much different from 65 fathoms or 119 m between the distances of 1000 and 2500 m from the coast of Ōsumi. Making an allowance for the slope of the sea bottom, the submarine lava stream seems to form a flat mound of a nearly constant height in the transverse section, much similar to the hill group of 120 to 400 m height situated above the village of Akobaru on the lower base of the western flank of Sakura-jima mountain.



Figs. 68 (upper) and 69 (lower). Diagrams showing Accumulation of Lava at Sea Bottom off the S.E. Coast of Sakura-jima.

PQ......A nearly N.-S. line forming the axis of the greatest submarine lava accumulation.
RS......A nearly E.-W. line at right angles to PQ.

BB......Original sea bottom.
AA......New sea bottom, or lava accumulation.
y......Depth below the sea surface, in fathoms.

32. Steaming circle (arcs). As will be seen from the sketch (fig. 70), which represents the views taken on April 30th, 1915, from a height of about 500 m above sea-level near Hikinohira, of the lower portion of the eruption field on the western side, a series of white small steam columns was issuing from the western portion of the lava area between Hakamagoshi and the new Karasu-jima bay (k, fig. 71), along a nearly closed ellipse about 100 m parallelly distant from the lava coast, whose diameters were about 1100 m and 500 m respectively in the N.S. and E.W. directions. (See figs. 71, 104, and 105.) The back side of the circle, near which there were also two short series of small steam columns, is located some distance outside the former coast line. This ellipse or circle of steam, which had already been noticed at the time of the present author's 2nd visit to Sakura-jima, in April 1914, still maintained nearly the same condition in Sept.–Oct., 1915,* and is likely to remain so for some time to come. The vapours, whose issue was generally most abundant in the early morning, were sometimes completely invisible in afternoon hours of fine days, being entirely dissolved in the warm air. The steam columns, whose usual height was 50 to 100 metres, were much augmented in force and rose to about 300 m above sea-level, after a heavy precipitation of rain as, for instance, on Oct. 1st, 1915.

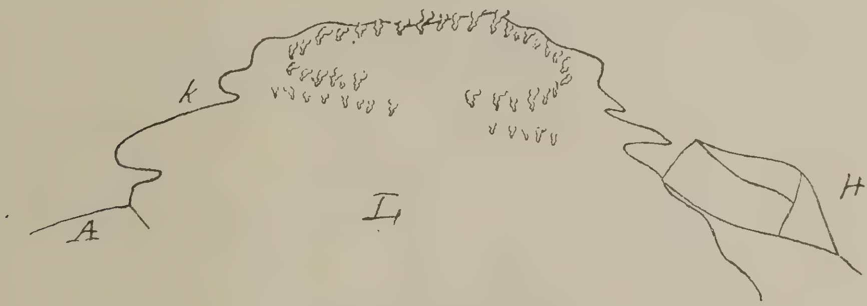


Fig. 70. View of the Steaming Circle on the Western Lava Field taken from the vicinity of the Lava Source No. 2 to the North of Hikinohira.
H......Hakamagoshi. A......Coast of Akamizu. L......Lava field.
k......Small inlet near the former Karasu-jima.

The *circle* of steam is evidently no other than a particular sort of the line of dislocation or subsidence, formed inside the boundary "moraine" of a lava field (§ 26), the sea-water soaked through which constituting the white smokes given out along it. The width of the marginal terrace, or the space between the lava edge and the curve of dislocation CC (figs. 71 and 105), is broader than in the case of the descent of a lava stream along a valley course, as the absence of barriers (mountain sides) allows the free side expanse of the lava in its first outflow.

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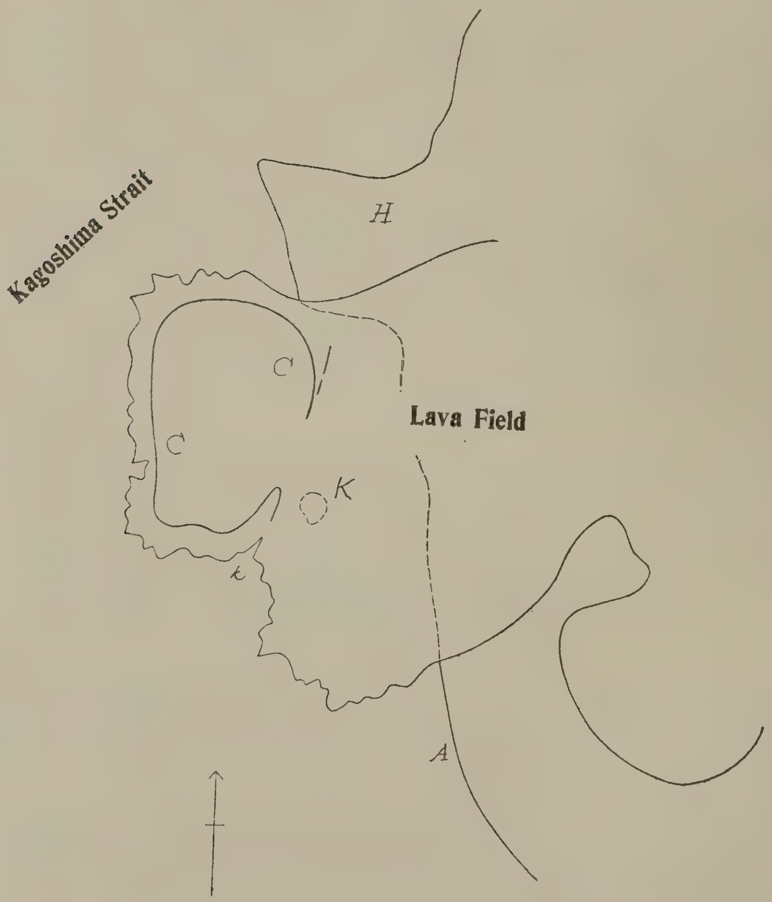
* On Sept. 28th, 1914, the steaming was taking place from about 30 different places along the circle situated inside the lava coast line.

Fig. 71. Plan showing the Position of the Steaming Circle (CC).



H......Hakamagoshi. A......Coast of Akamizu. K......Karasu-jima (buried).
Dotted line between A and H marks the former sea-coast.

33. Absence of steaming circle on Arimra lava field. A striking feature in connection with the steaming circle on the western lava field considered above is the absence of a similar phenomenon on the much more extensive Arimra lava field, with the result that at the end of 1915, the latter became perfectly quiet with practically no issue of smokes. The cause of this difference seems to be two-fold, as follows :—Firstly, as the bottom of the strait between Kagoshima and Sakura-jima is shallow (with the maximum depth of only about 23 fathoms) and of a gentle declivity, the inner hot mass of the lava stream tended to remain in its position, and conserve its heat ; while, as the sea off the southern coast of Sakura-jima is deep (maximum original depth=90 fathoms) and of a steep gradient, the interior lava mass must have progressed swiftly on, tending to discipate the heat with a comparatively quick rate. Secondly, unlike the western lava field whose surface is practically above water, the Arimra lava is submerged for an extension of about 4 km, thereby sustaining a weight of water column increasing at the top surface near the front margin of the lava stream to a depth of about 30 fathoms. This pressure must effectively prevent the escape of steam from the surface of the submerged lava field except in the form of bubbles through shallow water, a fact which has actually been observed.

Fig. 72.

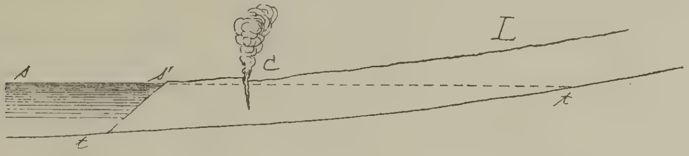
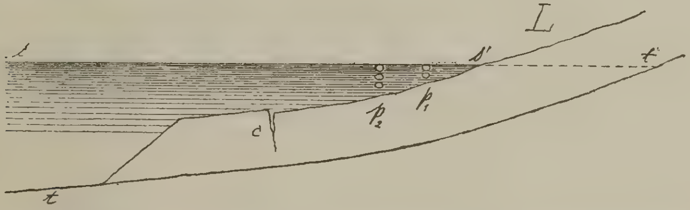


Fig. 73.



Figs. 72 and 73 illustrate respectively the Existence of Steaming Circle on the western lava field and the Absence of it on the Arimra lava field.

34. Temperature of fumaroles. (See Table IV.) The thick layer of ashes and sand covering the higher portion of the lava streams on the eastern side maintained in 1914 and 1915 still fairly high temperatures of over 80° C. This heating effect seems to be due to the hot gases and steam set free from the buried lava masses which were partly diffused among the pumice bed and loose surface deposits, and partly escaped into the air along innumerable fissure lines, forming the miniature fumaroles and solfataras. The temperature of these latter was sometimes above 100° C, but was reduced, with the decline of their force, to a degree not much different from that of the ash and sand layer.

On the western lava field there was no very thick covering of ash and sand, and the temperature measurements given in Table IV have been made mostly at the vicinity of the lava source to the S.W. of the 400 m hill (1½ km to the N.W. of Hikinohira), where the ridge ground was very much cracked and dislocated, and was emitting hot gases of bad smell. In April 1914, one of the small fumaroles indicated a temperature of 87° C. In April 1915, the ground, where no actual fumarole existed, had in an instance a temperature of 76° C, while a fumarole indicated at a 25 cm depth a temperature of 90° C. On the whole, it seems that there existed no special difference in the temperatures of the fumaroles and solfataras between the E. and the W. side lava fields. According to Table IV, there were cases in which the surface temperature of the fumaroles decreased from 87° C to 68° C in the course of one year between April 1914 and April 1915, and also from 87° C to about 70° C during the 5 months, April to Sept., in 1915. Other, possibly newer, ones had much higher temperatures of 88°.6 to 91°.0 at the latter date.

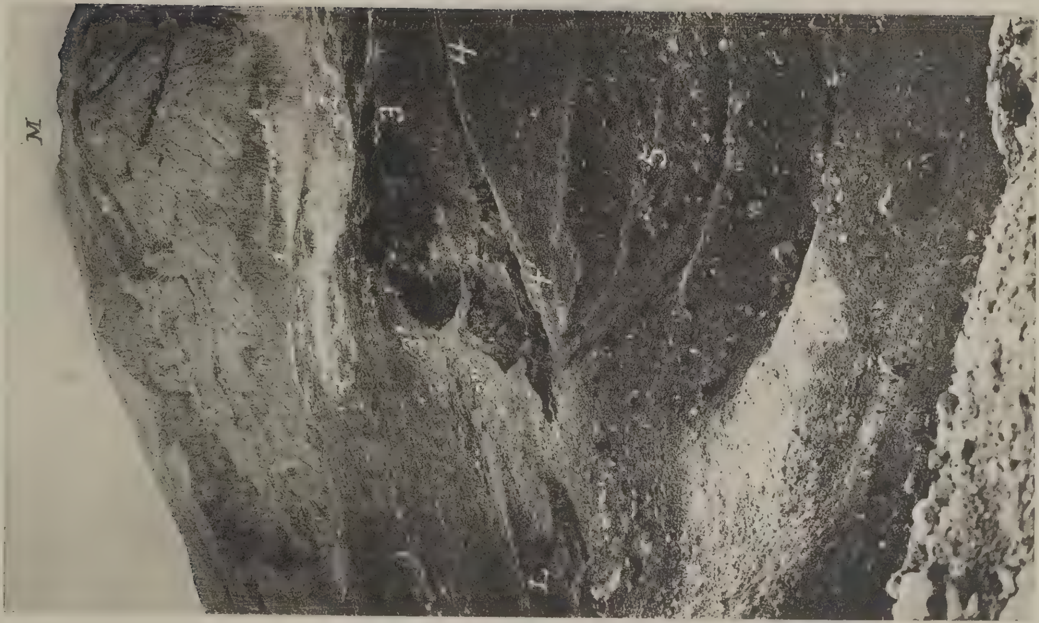


Fig. 75. General view of the Eastern Craterlets Series taken from the S.E. shoulder of Nabe-yama. Minami-dake top (M) is shown on the background.
1′, Uppermost "chimney." 1, 2, 3, 3′, 3″, 4′, 4, 5 are respectively Nos., 1, 2...5 craterlets.

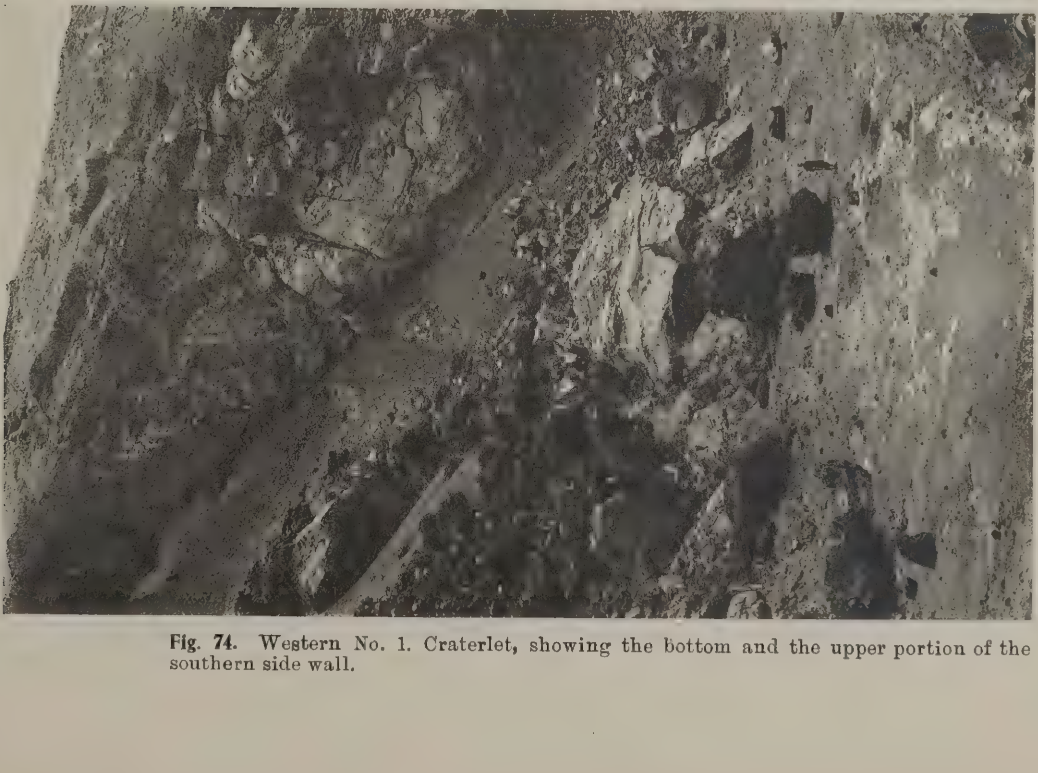


Fig. 74. Western No. 1. Craterlet, showing the bottom and the upper portion of the southern side wall.

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Sakura-jima Eruption of 1914. (F. Omori, photo.)

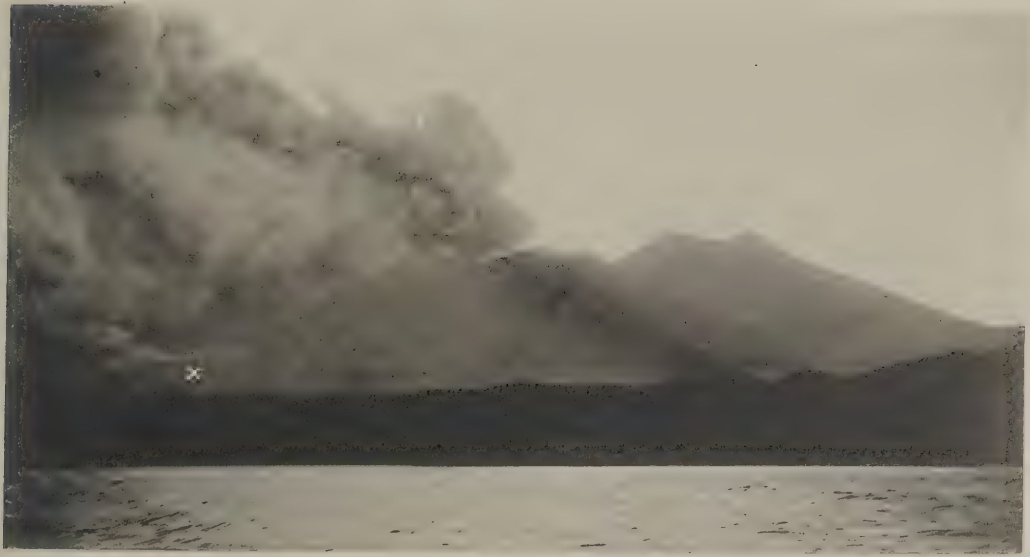

Fig. 76. Sakura-jima and the eastern outbursts seen from the east, showing amongst the others the horizontal ejection of white smokes (×) from the uppermost orifice, or the "Chimney". (Jan. 16th, 1914.)

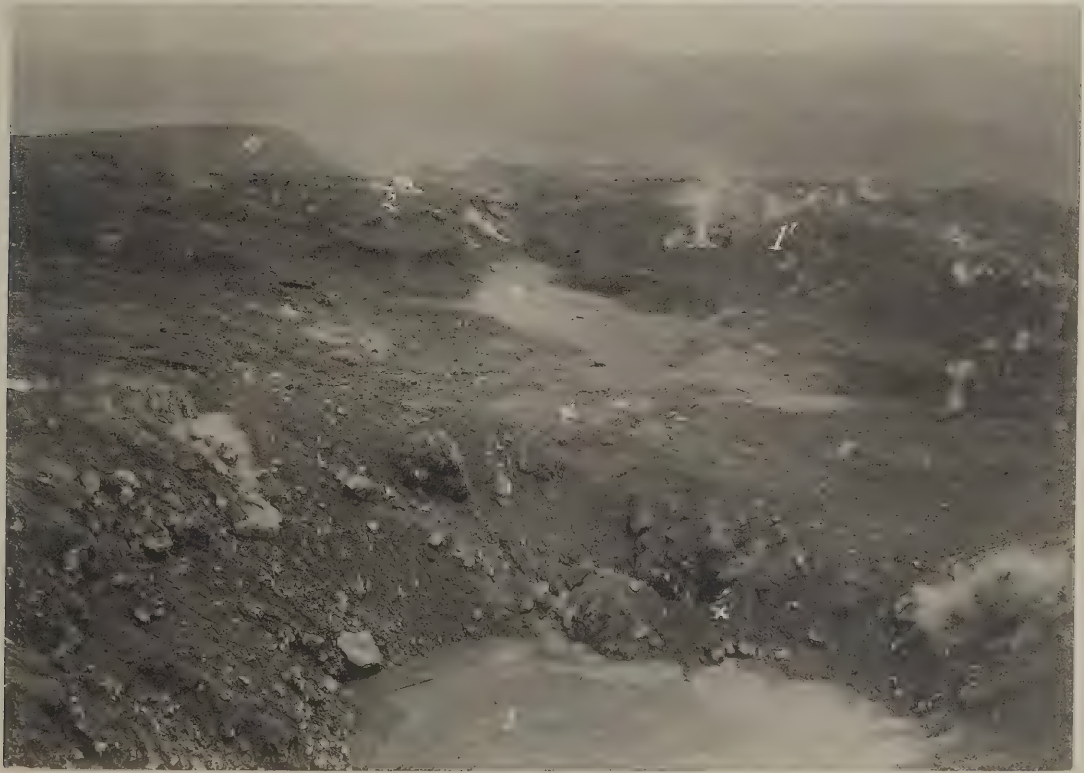

Fig. 77. General view of the Eastern Eruption Field taken from the upper rim of the No. 1 Craterlet (1). From the latter a depression zone or Eruption Canal (×......×) leads toward the Nabe-yama Crack. (April, 1915).
(N), Highest point of Nabe-yama. (1′), A small craterlet. (2), Craterlet No. 2.

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Sakura-jima Eruption of 1914 : the Outbursts from the Eastern Craterlets seen from the north eastern or Krokami side. (F. Omori, photo.)

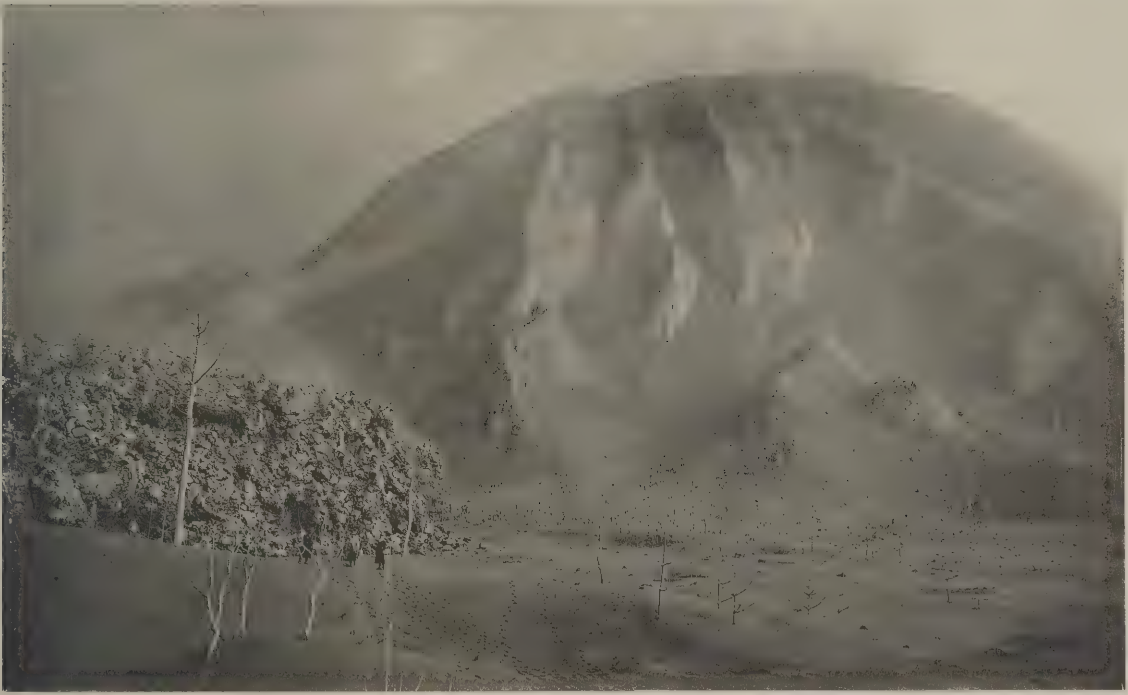

Fig. 78. Nabe-yama, seen from the N.E., with a lava stream at the left-hand side base. (Jan. 23rd, 1914.)

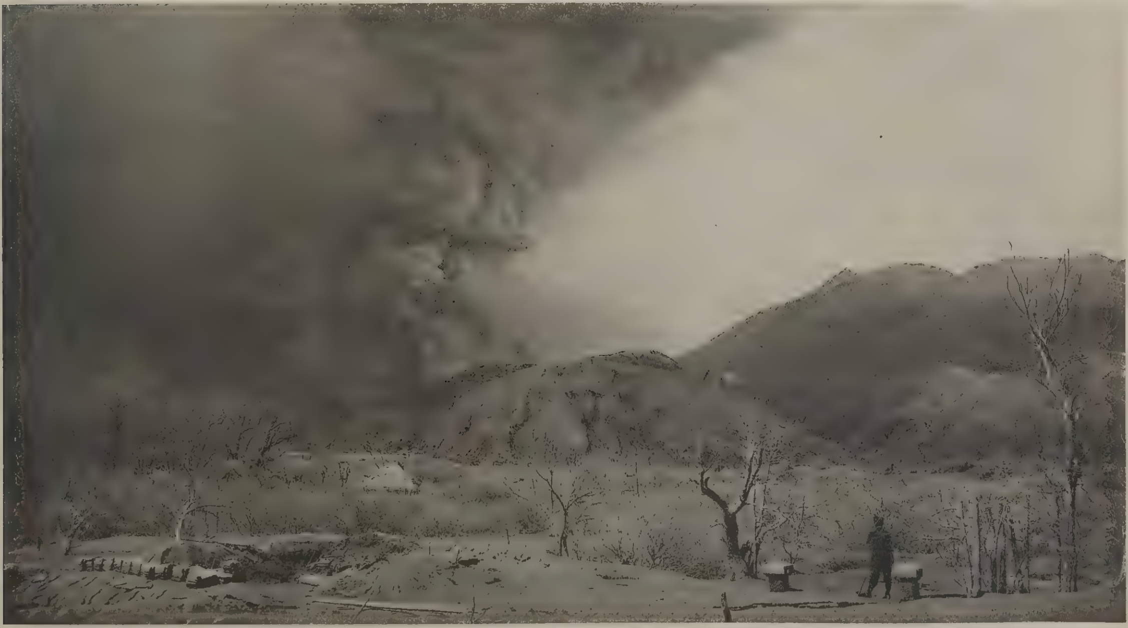

Fig. 79. Nabe-yama (at centre of figure) seen from the plateau ground of Krokami, with the smoke columns rising principally from the No. 4 and the more eastern craterlets. The central and S. peaks of Sakura-jima are shown at the right-hand side. The heads of two stone gate posts, near which a man is standing, are shown out of the accumulated layer of pumice and ash. (April 1914.)

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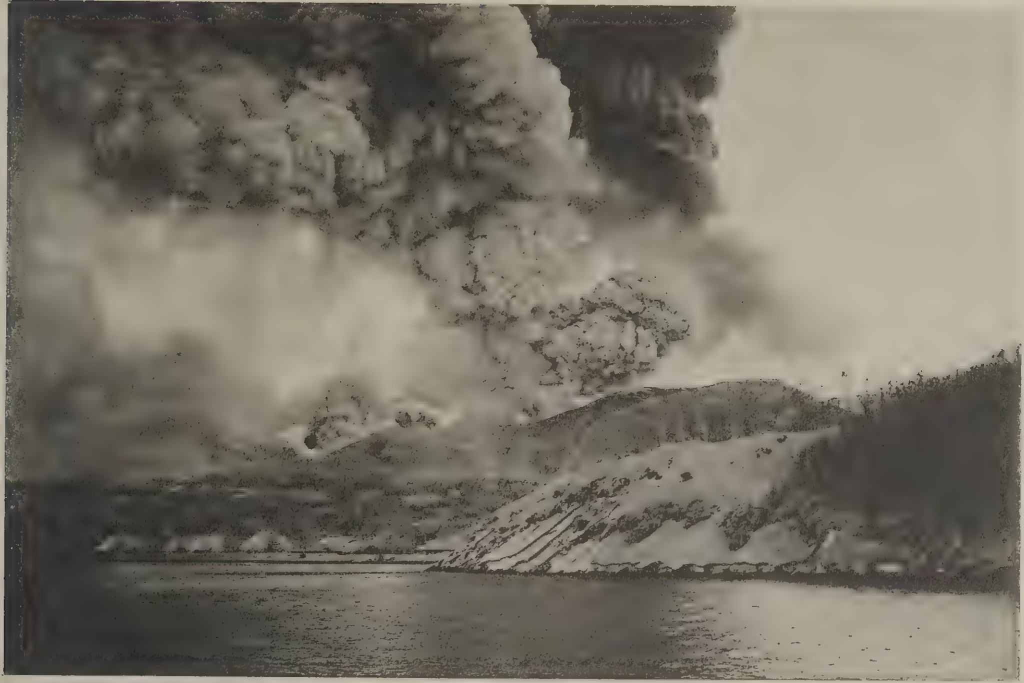

Fig. 80. Nabe-yama seen from the E. on Jan. 30th, 1914, the eruptions taking place actively from the Craterlets Nos. 2, 3, 4, 5, and 7. The houses belong to the Krokami village. (I. Watanabe, photo.)

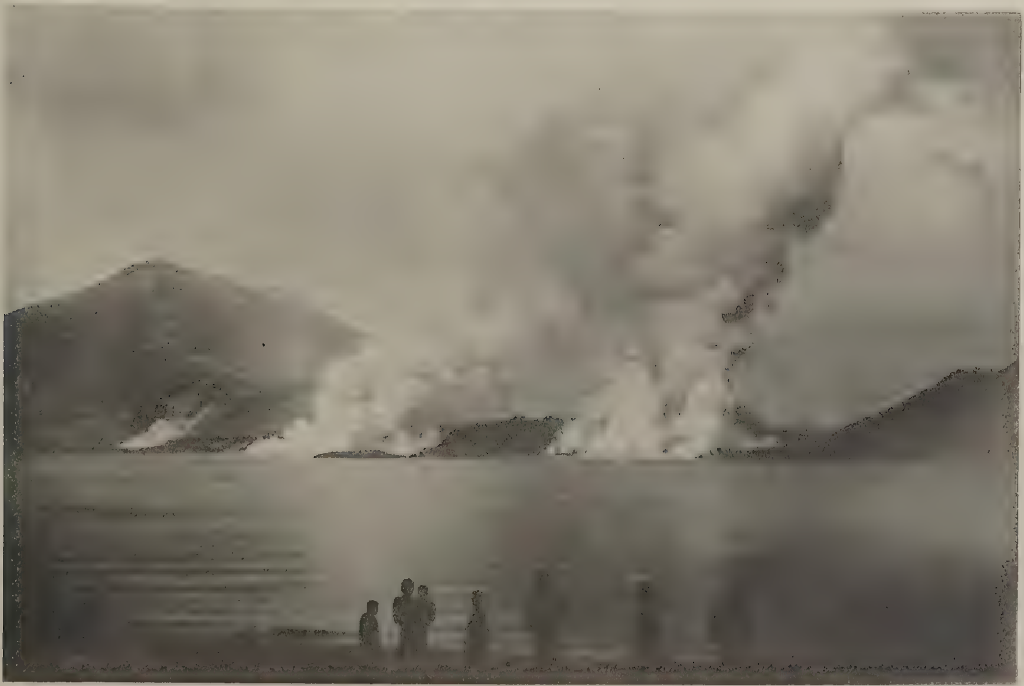

Fig. 81. View of the Sakura-jima peaks (left-hand side) taken from the coast of Kaigata, near Tarumizu (Ōsumi). An islet (Arimra-jima) is in existence in front of the left-hand side vapour column. (Feb. 4th, 1914. R. Higo, photo.)

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Sakura jima Eruption of 1914. (April, 1914. F. Omori, photo.)

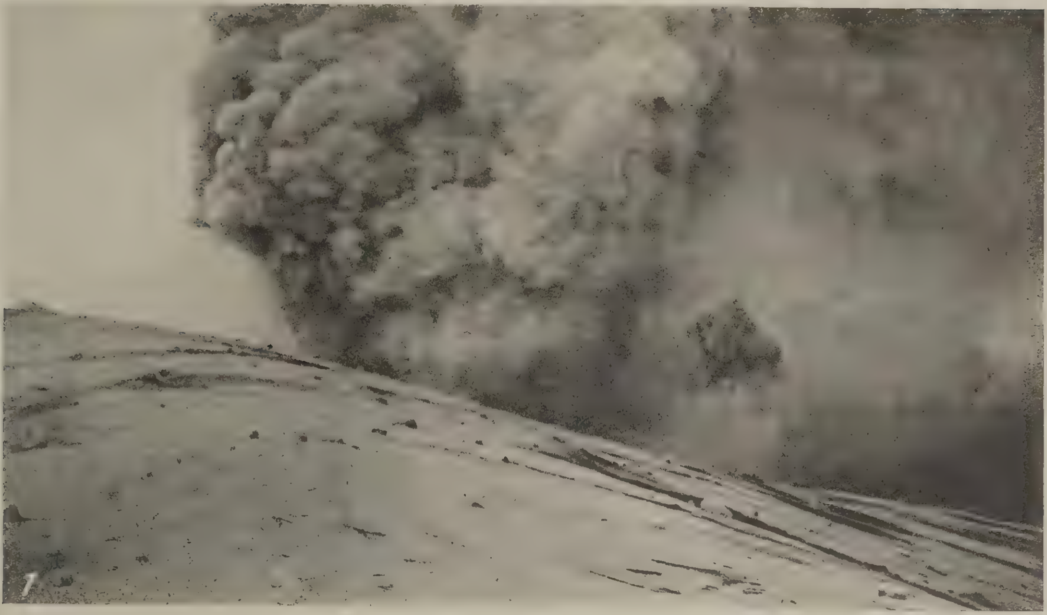

Fig. 82. Outbursts from the Eastern Craterlets Nos. 3 and 4 seen from the W. part of the top ridge of Nabe-yama (1).

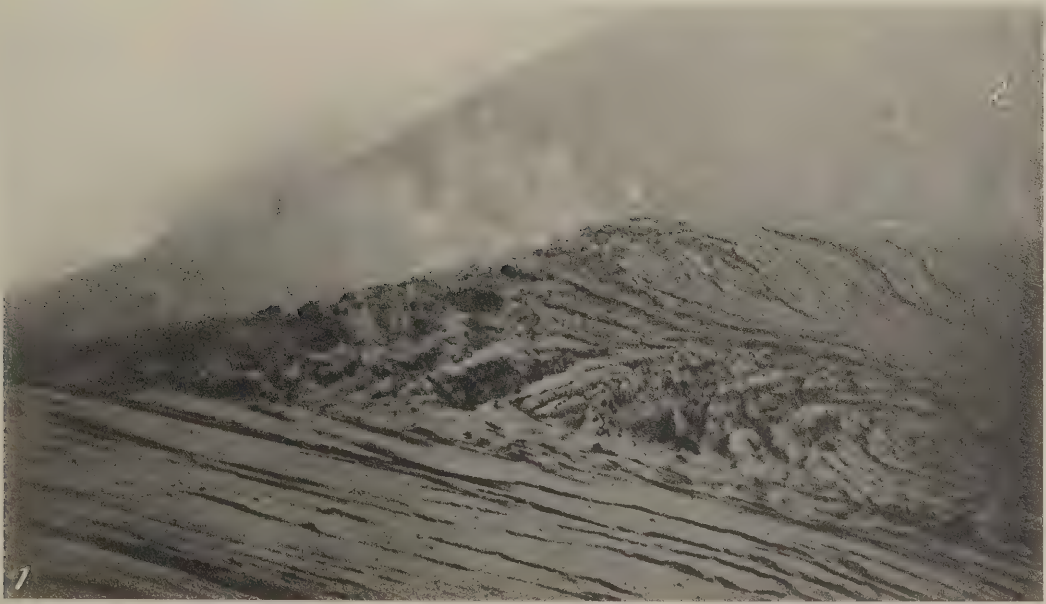

Fig. 83. View from the same point of the ash-covered upper part of the lava cascade which flowed from the Eastern No. 2 Craterlet to the valley between the W. flank of Nabe-yama (1) and Gongen-yama. (2), Eastern side of Minami-dake.

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Sakura-jima Eruption of 1914 : the Nabe-yama Lava Cascades. (April, 1915. F. Omori, photo.)

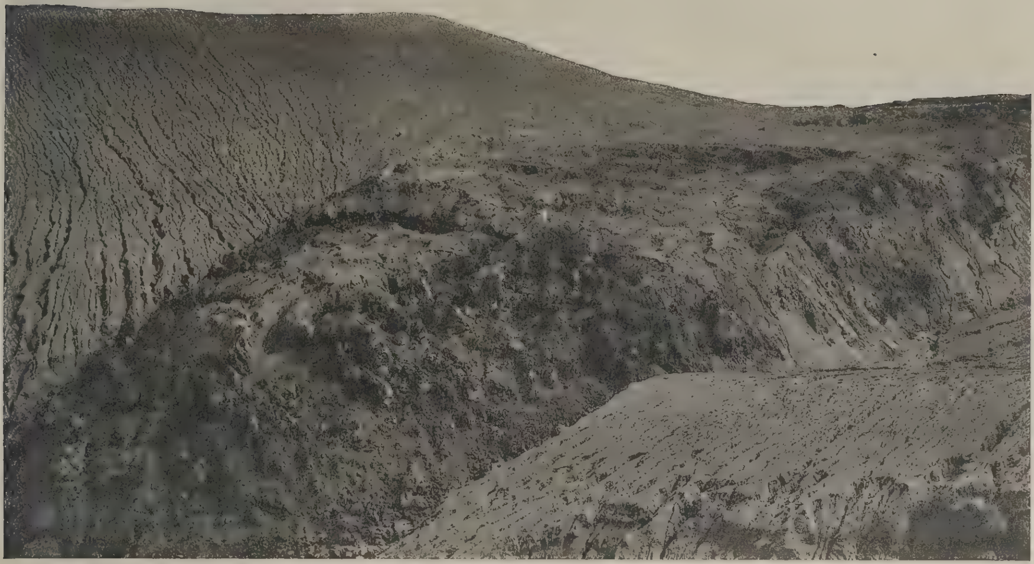

Fig. 84. Lava flow on the N.W. flank of Nabe-yama, seen from Gongen-yama.

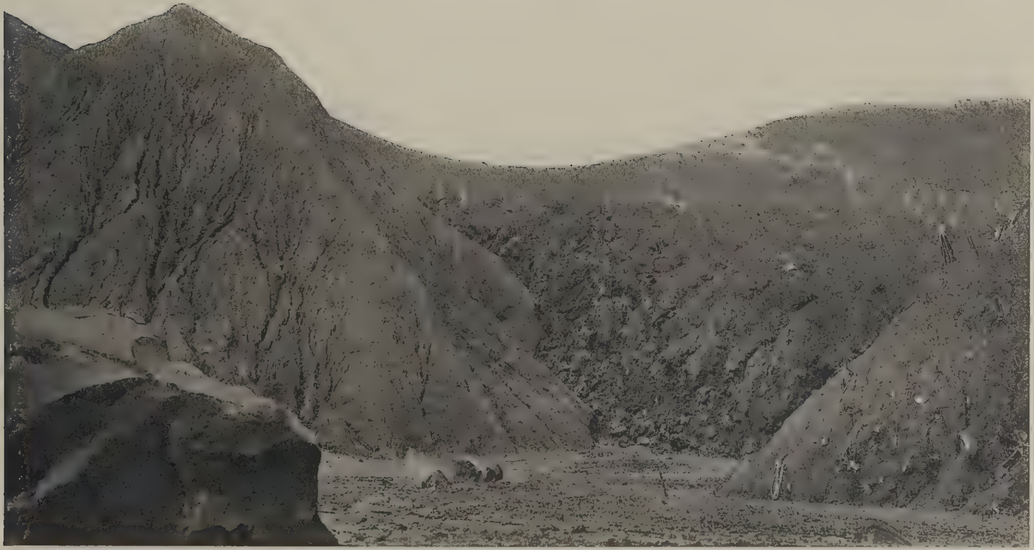

Fig. 85. Lava flow into the interior of Nabe-yama, seen from the opening on the east.

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Sakura-jima Eruption of 1914 : View of the Eastern Eruption Field. (F. Omori, photo.)

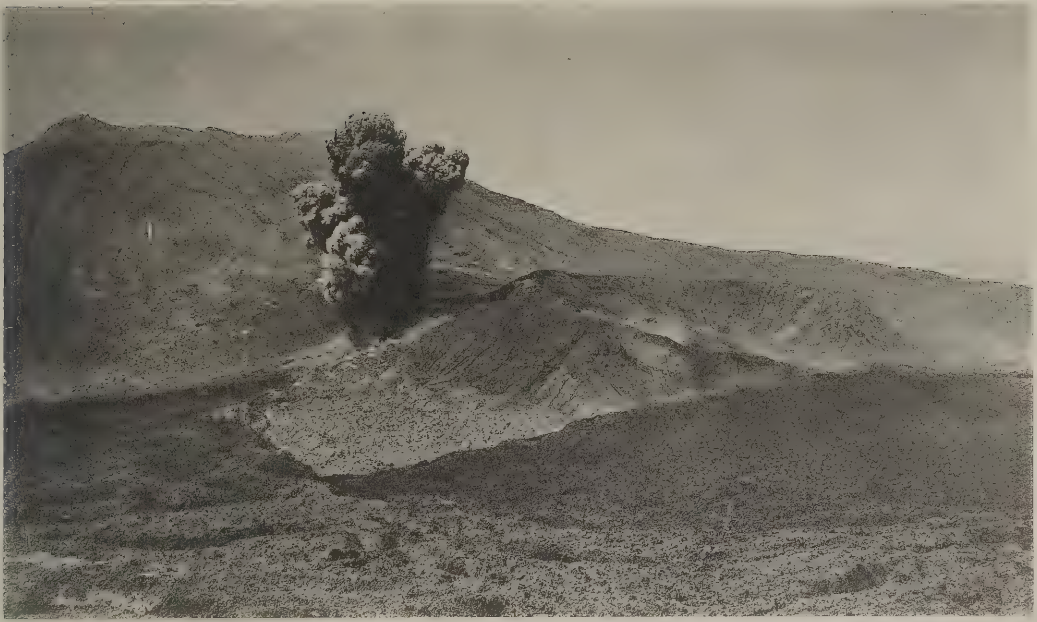

Fig. 86. Nabe-yama and an outburst from the Craterlet No. 4, seen toward the northwest from the top of Sakkabira Promontory. The central peaks of Sakura-jima are shown on the background to the left-hand side. (April, 1915.)

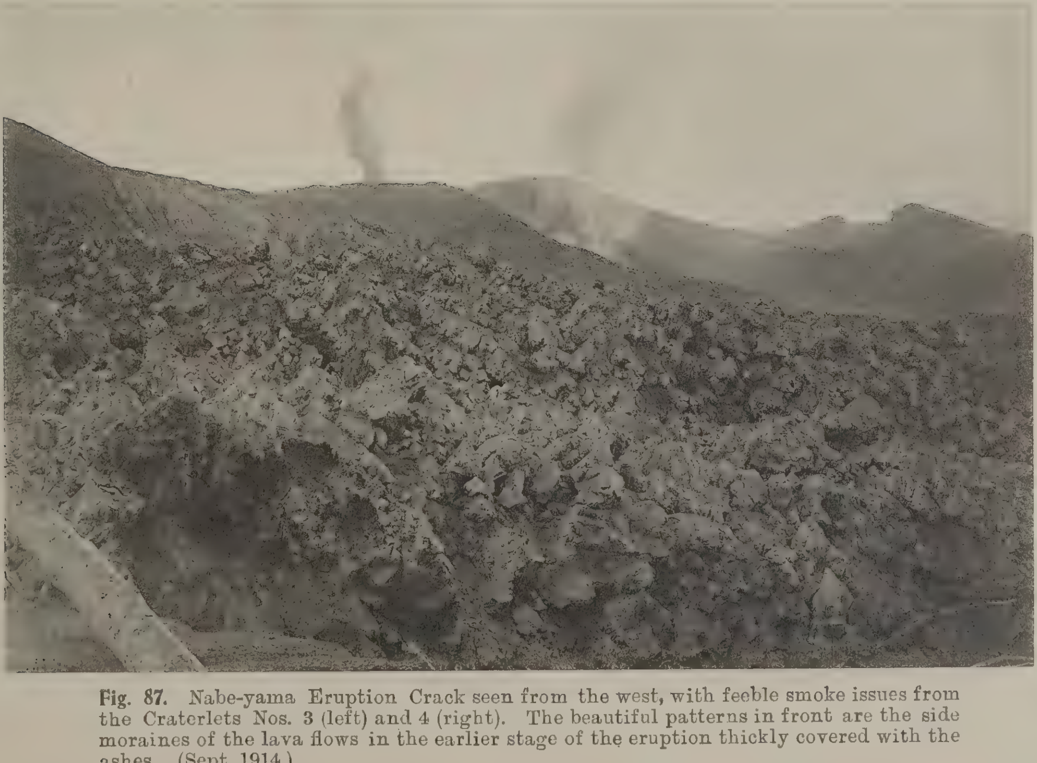

Fig. 87. Nabe-yama Eruption Crack seen from the west, with feeble smoke issues from the Craterlets Nos. 3 (left) and 4 (right). The beautiful patterns in front are the side moraines of the lava flows in the earlier stage of the eruption thickly covered with the ashes. (Sept. 1914.)

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Sakura-jima Eruption of 1914. (F. Omori, photo.)

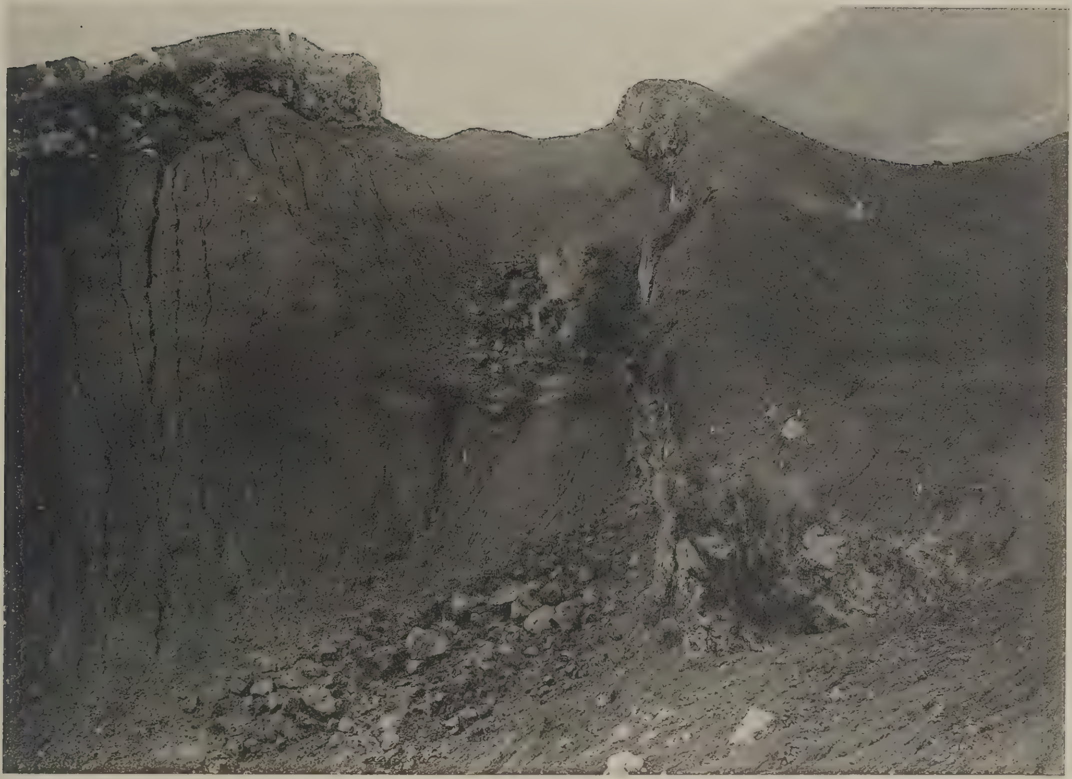

Fig. 88. Higher portion of the Eastern Branch of the Nabe-yama Eruption Crack, showing the ashy material of Nabe-yama and the new lava layer coated with ashes. (April, 1915.)

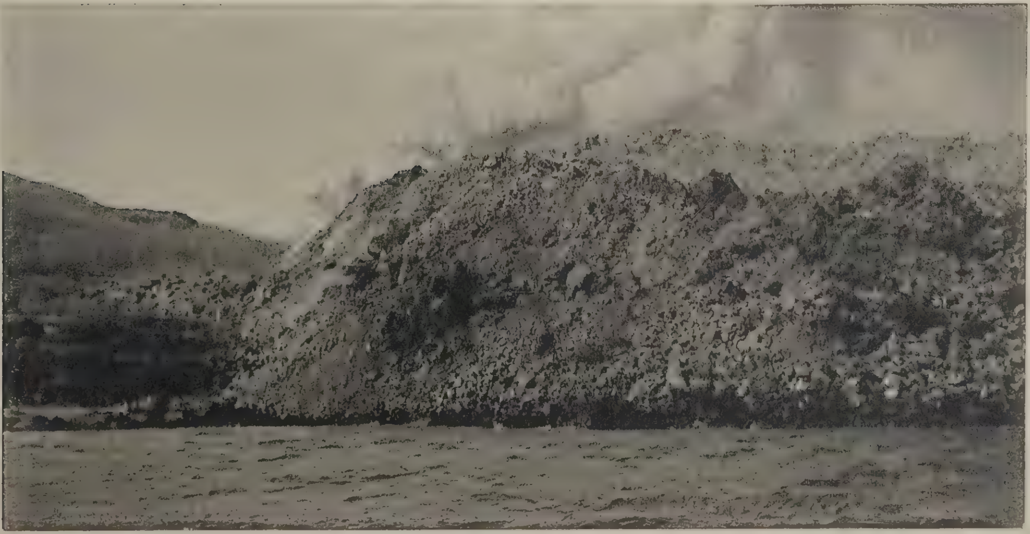

Fig. 89. S.W. terminal corner of the Eastern Lava Field, at the beach between Yuno-hama and the buried village of Arimra. (April, 1914.)

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Sakura-jima Eruption of 1914 : the Eastern Craterlets.

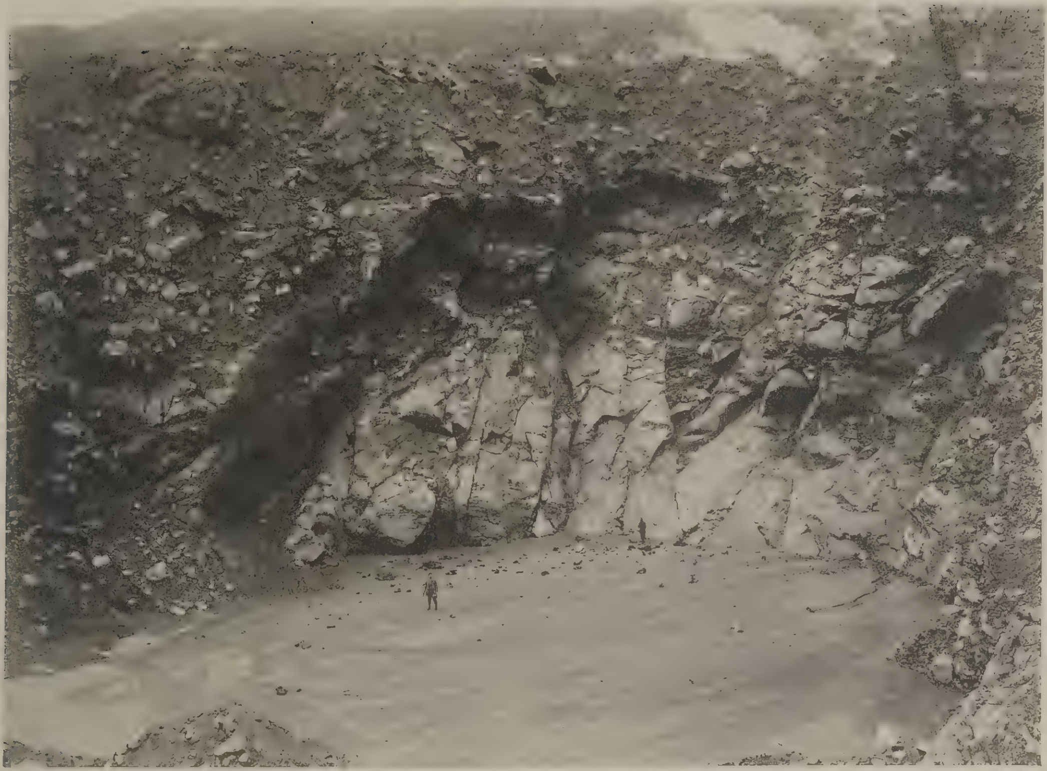

Fig. 90. Craterlet No. 1, seen from the lower or east rim. The bottom is completely filled with pumice and sand.

(April, 1915. F. Omori, photo.)

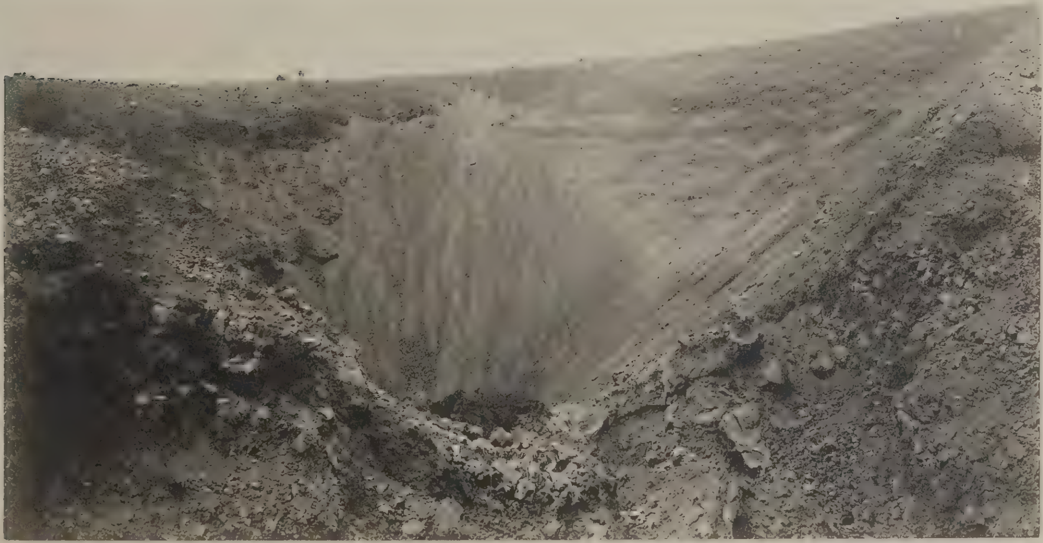

Fig. 91. Craterlet No. 4, seen from the ridge separating it from the lower and secondary craterlet No. 4′. At the bottom, a loose-looking mass of lava is shown.

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TABLE IV. Temperature of Fumaroles.

(Figures within brackets denote the simultaneous air temperature.)

Date of Measurement.	Place.	Temperature.
	Western Eruption Field.	
April 8, 1914.	Fumarole on the ridge to the S.E. of 400 m Hill, above the two small secondary craterlets.	87.°0 C
April 30, 1915.	Fumarole at a locality nearly identical with the above, 412 m above sea-level : at surface.	68.°0 (22.°5)
	Do. : ½ feet below the surface.	80.°5
" "	At the S.E. base of 400 m Hill, above the lava source : ordinary ground, at 1 foot depth.	76.°0 (21.°8)
	Do. : where a slight fumarole was issuing, at 25 cm depth.	90.°0
" "	Fumarole on the W. inner side of No. 1 craterlet, near Hikinohira.	88.°6
	Eastern Eruption Field.	
April 22, 1915.	Fumarole orifice, on lava field thickly coated with ash, at the foot of the slope to S. of No. 1 craterlet, 315 m above sea-level.	87.°0 (14.°5)
Sept. 22, 1915.	At the same locality as above : feeble fumaroles.	61.°5 ; 63.°8 ; 69.°5 ; 58.°0 (27.°4)
" "	*Do.* : fumarole issuing from a fissure 1 m long, ½ m deep, and 15 cm wide, at the base of a lava block 1 m in dimension.	Over 127.°
" "	*Do.* : orifice of a very small fumarole.	74.°5
" "	*Do.* : " "	91.°0

35. Changes in mountain profile. As may be seen from figs. 2 and 3 (Pl. XXXIII), the change in the general E.S.E.–W.N.W. profile of Minami-dake consists on the western side in a height increase to the maximum amount of about 80 m for the slope below the level of 400 m; this being the resultant effect of the thick coating afforded by the lava outflow combined with the elevations and depressions to which the convulsed region in the immediate vicinity of the craterlets must have been subjected before and during the eruption. On the eastern side, the change has been two-fold as follows :—Firstly, the southern portion of Nabe-yama had its height reduced, to the maximum amount of nearly 100 m (§ 3), probably due in the main to the exploding away of the surface layers of the hill along the Eruption Crack ; and secondly, the gentle slope between the craterlets Nos. 1 and 4 was elevated in height, to the maximum amount of about 70 m, due partly at least to the accumulation of the lavas. The marked horizontality of the two new successive ground steps between the craterlets Nos. 1, 2, and 3, seems to have been produced by the upward overflow of the magma from the second and third eruption vents respectively.

The top outlines of the central peaks of Sakura-jima, namely, Kita-dake, Naka-dake, and Minami-dake, indicated in the views taken from Kagoshima, were not sensibly modified by the eruption of 1914. (See figs 9, 10, 11, and 36.)

Chapter IV. Blocking Up of Seto Strait.

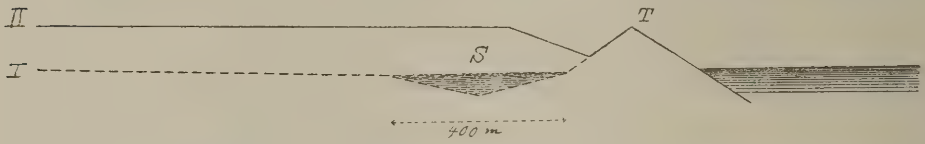
36. Blocking up of Seto Strait. A portion of a small colline, 100 to 200 m in height, projecting toward S.S.E. from the southern shoulder of Nabe-yama, remains uncovered by the flowing material, with the remnants of smashed forest trees still standing on it. This forms, in fact, the boundary between the lava masses which spread to the south-east of Nabe-yama and descended into Seto Strait and those which, originating from the craterlets Nos. 1 to 5 situated to the west of the latter, ran mainly southwards and buried the villages of Waki and Arimra and extended 4 km further under the sea toward the S.S.W. The Seto strait lava issued, probably on the night of the 12th-13th, Jan. 1914, mostly from the craterlets Nos. 6, 6′, 6″, and 7 situated in the Eruption Crack of Nabe-yama, and descended along the straight N.-S. valley running from the east foot of the latter, through the length of 2 km to the small plane ground of the village of Seto. From accounts of the eye witnesses, it seems that the molten stream in question, which had buried under it the village of Seto, began to discharge itself into the bottom of the strait already at about 10 a.m. on the 13th. When seen 3 days later on, namely, on the afternoon of the 16th, the strait water was vigorously sending up dense white clouds of vapours. (See fig. 106.) The narrowest portion of the strait, about 600 m in length, 400 m in width, and at centre 29 to 40 fathoms in depth, was quickly reduced in dimension and finally blocked up on Jan. 29th, 1914, or 17 days after the commencement of the eruption; the accumulation of the submerged lava mass having then reached up to the water surface and converted the Sakura-jima island into a peninsula.

The blocking up of the Seto strait, which was certainly a remarkable event, was, in reality, a very natural consequence of the outflow of a large amount of lava, whose thickness exceeded, not rarely, 100 metres, which is double the minimum central channel depth of 29 fathoms or 53 metres. The further height increase of the lava filling the strait progressed at first rapidly, such that it rose 54 m above the sea surface, according to the estimation made from the photographs taken from a distance at the commencement of April, 1914; the hot rock mass, which pressed hard and partially crushed the former Ōsumi coast, rendering impassable the road along the latter at an elevation of 4.3 m above sea-level. (See fig. 107.) A new road, which was made 36 m above the old, was again brought in contact with the lavas at the end of September in the same year, when the elevation above the sea-level was estimated to be 101 m as stated below. Thus the average rate of the lava accumulation at the "strait" (isthmus) was at first approximately 3.5 m per day, reduced in the course of a few subsequent months to 0.3 m per day, as follows :—

Between the 14th and 29th, Jan. 1914..............3.5 m/day.
,, Jan. 29th and April 12th, 1914...........0.69 ,,
,, April 12th and Sept. 27th, 1914 ....0.3 ,,

Since September 1914, there was no remarkable alteration in the condition at the "strait"; the result of a simple triangulation executed on April 25th, 1915, with respect to the highest point of the Seto lava, being as follows :—the elevation above sea-level=105 m ; the horizontal distance from the Ōsumi coast=170 m. (See fig. 92.)

Fig. 92. Diagram showing the Approximate N.S. Cross Section in April, 1915, of Seto "Strait" at its narrowest portion.



I......Original Seto (Sakura-jima) beach ground. II......New lava accumulation.
T......Tobashira promontory (lower part of Sakkabira), Ōsumi.
S......Former sea surface at the Seto strait.

The variation with time of the height of the Seto strait lava is illustrated in fig. 95. The height (= h) in question can also be estimated roughly by comparison with that of the Sakkabira hill (h′= 324.8 m) from the pictures taken from sea respectively on Sept. 27th, 1914 (fig. 17), from a distance of 6 km to the S.S.W., at 1 m height, and on Sept. 29th, 1915, from a distance of 13 km to the S.W., at 4 m height. We have: $n\,h = h' + (n-1)\,d$, in which n is the ratio of the apparent height of Sakkabira to that of the Seto strait lava as measured from the photograph, and d the height below the visible horizon. The results of calculation are as follows:—

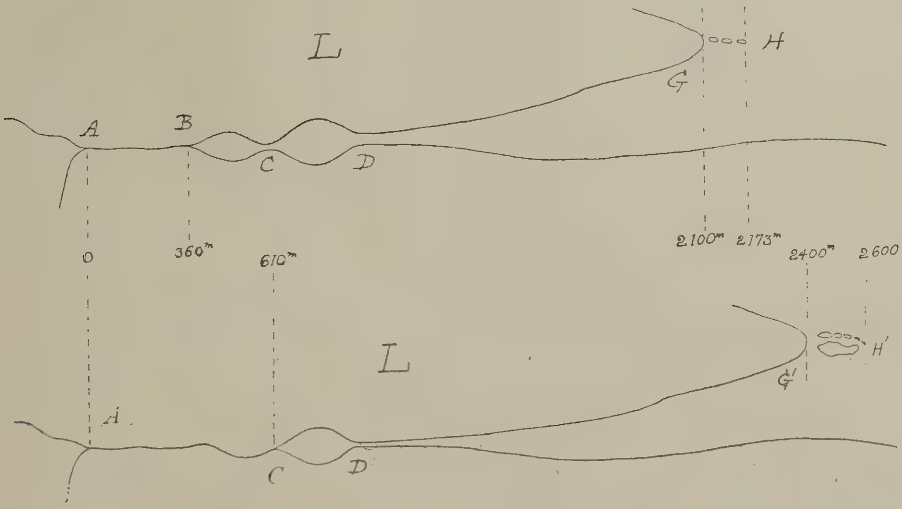
Height of Seto strait lava, on Sept. 27th, 1914=101 m.
,, , ,, Sept. 29th, 1915=106

As stated before, the height in question was 105 m on April 25th, 1915; it follows therefore that the elevation of the Seto strait lava was not much increased during the course of the next 5 months.

37. Contact length. (See figs. 93, 94, and 96.) On April 12th, 1914, the contact AB of the Seto lava with the Ōsumi coast was 1200 feet in length, being continued on the east end to a hot water area BC, which was converted at low tide time to a pond 690 feet in length. In September of the same year, the latter was also almost entirely filled up, so that the contact became 1830 feet in

Fig. 93. Plans showing the Increase of the Contact Length and the Extension of the Seto "Strait" Lava Outflow.

The upper figure relates to the condition on April 12th, 1914.
The lower figure „ „ April 25th, 1915.



L……Seto strait lava. AD……Coast of Ōsumi.

Time.	Contact Line.	Steaming Pond.	Front End of Lava Outflow.	New Lava Islets.
April 1914.	AB	BC	G	H
April 1915.	AC	CD	G′	H′

The numbers indicate in metres the distances of the points B, G, H, and C, G′, H′ from the western end A of the contact line.

length, with a new adjacent pond CD on the east end. Since then the extension of the Seto "strait" contact was only slightly increased, being, on April 25th, 1915, of the length of 2000 feet, continued to the pond CD, 840 feet in length. The average daily rate in 1914 of the increase of the contact length was 5.0 m in February and March, and 1.2 m in April to September, further reduced to 0.24 m in Sept. 1914 to April 1915, as follows:—

Jan. 29th to April 12th, 1914..............	5.0 metres/day.
April 12th to Sept. 25th, ,, ...	1.2 ,,
Sept. 25th, 1914, to April 25th, 1915......	0.24 ,,

38. Extension of Seto strait lava. (See figs. 93, 97, and 103.) The total extention, that is to say, the direct distance between the western or Sakkabira end of the Seto "strait" and the eastern extremity of the lava outflow opposite the coast of the village of Ushine, was in April, 1914, about 6840 feet, while the new lava islets at the apex extended for a further distance of 240 feet. The total length was increased to 7280 ft. on Sept. 25th, 1914, and to 7950 ft. on April 25th, 1915; in other words, the Seto lava stream progressed, during the interval of the 12 months between April 1914 and April 1915, about 1100 ft. eastwards, giving the following rate of linear elongation:—

April 14th to Sept. 25th, 1914,...........	0.82 m per day.
Sept. 25th, 1914, to April 25th, 1915....	0.97 ,,

Thus the average change rate in the total length remained, between April 1914 and April 1915, nearly steady and equal to 0.9 m per day; while that during the first 3 months, between Jan. 13th and April 14th, 1914, was of course much higher and equal to 23 m per day approximately. The slow progressive movement of the lava has thus been continued already for 1½ years.

A fact of special interest is in connection with the small detached rocky masses or islands, which are none others than the "lava islets" each with a peculiar cleavage canal (Chapter V). In April 1914, the islets, which had been formed at the apex of the lava outflow, stretched, in the direction of the prolongation of the latter, for a space of 240 feet. In April 1915, however, the corresponding distance was increased to 690 feet. This fact leads to the conclusion that the islets in question stand on the front submerged base of the lava stream, whose gradual forward movement was probably the cause of the increasing distance between the foremost islet and the promontory.

39. Current and water temperature at Seto "strait." On April 12th, 1914, at 4 p.m., the temperature of the sea-water along the Ōsumi coast was 21°.0 C. at the mouth, and 25°.5 at the mid-length of the Ushine bay*, being increased up to 52°.0 at the head of the latter. In the steaming pond BC (fig. 93) the water temperature varied between 62° and 73° C., while the maximum value of 90° C. was verified at its source B. When observed at a little past 4 p.m., just after the time of the lowest tide, a slight current was issuing out from the latter point, suggesting the existence of a possible water communication through the masses of the lava filling the "strait." This supposition was, however, obviously not true, as will be seen from the facts observed on Sept. 25th of the same year. On that day, at 2–3 p.m., when the tide was falling, hot waters of 90°.6 to 93°.7 C. in temperature were streaming close to the coast of Ōsumi out of the foot of the western or Tarumizu side of the Seto lava. At the same time, there was also an outflow of water on its eastern or Ushine side. Again, at the source of the steaming pond adjacent to the eastern end of the contact line, hot waters of 88.°5 C. was

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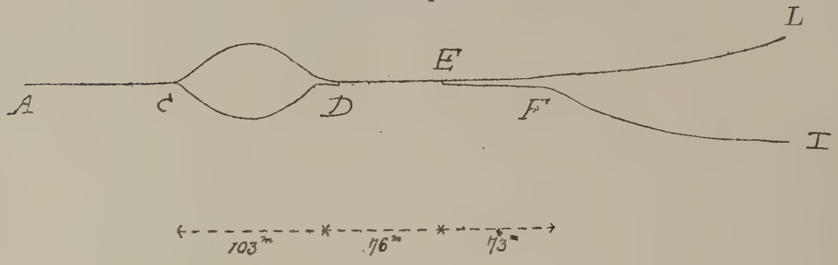
* The bay newly formed between the Seto strait lava promontory and the Ushine (Ōsumi) coast.

Fig. 94. Plan showing the condition of the Contact Line at Seto Strait in April 1915.



EL......Seto strait lava.
A (west)-I (east)......Coast of Ōsumi.
AC......Contact line.
CD......Steaming pond.
DE......Beach which was dried up at low tide time.

streaming out from among the lava masses with a velocity of about 0.3 m per sec.; while, at its outlet channel, about 2 m in width and 0.3 m in depth, the water with a temperature of 68.°5 C. was flowing out at the rate of about 0.45 m per sec.

Observations made on April 25th, 1915. (I.) Eastern End of the Contact Line. (See fig. 94.) At 2 p.m., (air temperature=17°.5 C.), when the tide was rising, the steaming pond CD, 340 ft. long and 160 ft. wide, was completely isolated from the external water body of the Ushine bay by the contact, at DE, of the sandy beach of the Ōsumi coast with the lava promontory L for the length of 250 ft., continued further to a narrow canal EF for 240 ft. At the head C of the pond CD, hot waters issued from among the lava masses and were flowing down or eastwards, the temperatures at the different points being 82°.0 ; 81°.7 ; 78°.5 ; 77°.5 C., etc. At the same time, there was at the lower end D of the pond, narrowed into a sort of small inlet, 4 m in length and 1 m in width, an inward or westward flux of water, whose velocity was 0.3 m per sec., the temperature being 75° to 72°.5 C. At the point between C and D diametrally opposite the side of the lava mass the water temperature was only 63.°0 C. In the canal EF, the water temperature

Diagrams illustrating the Increase in the Height, the Contact Length, and the Total Extension of the Seto "Strait" Lava.

(Jan. 1914 to May 1915.)

Fig. 95. Height of the Seto "Strait" Lava above sea-level.

Fig. 96. Length of the former Coast of Ōsumi in Contact with the Seto "Strait" Lava.

Fig. 97. Extension of the Seto "Strait" Lava between its E.N.E. Front Edge and the Sakkabira Promontory.

Fig. 95.

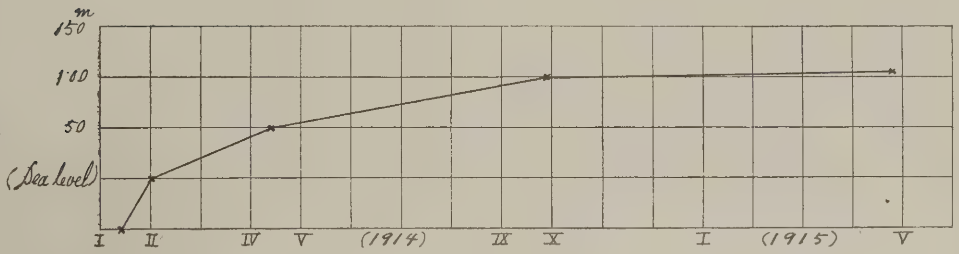


Fig. 96.

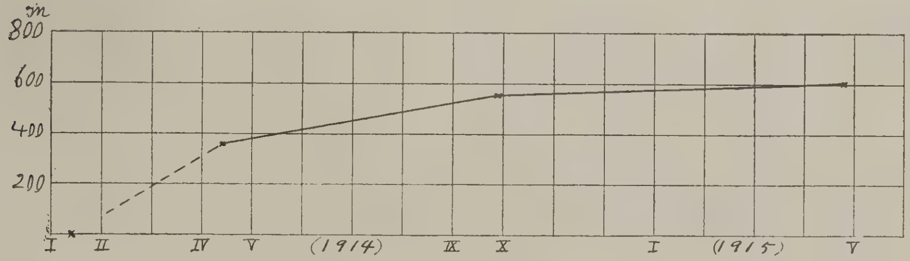
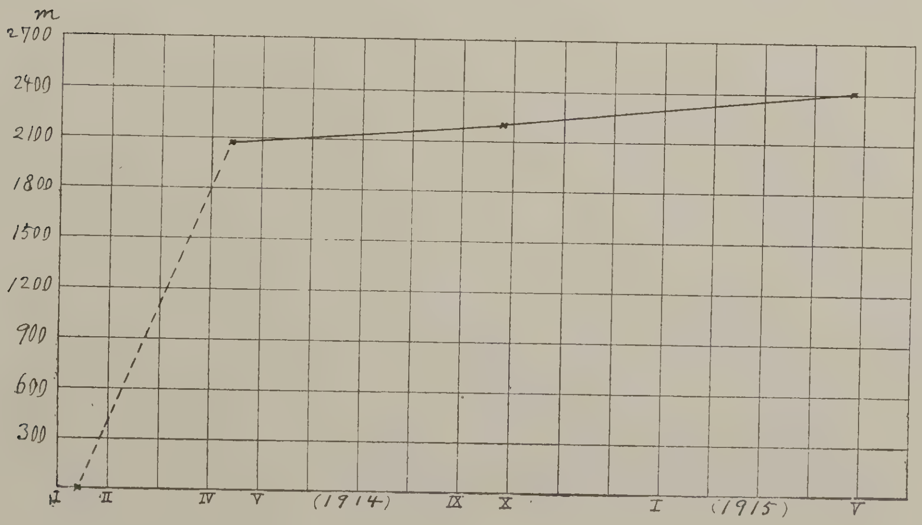


Fig. 97.



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was 53° C. at E and 57° C. at F ; while at the opening, or mouth, of the Ushine bay, the temperature was reduced to 20.°8 C. (II.) Western End of the Contact Line. (See fig. 98.) At 5 p.m., (air temperature=15°.0 C.), when the tide was still rising, the water temperature along the west end margin (AB) of the Seto strait lava was 87°.5 to 89° C. at the Ōsumi coast, and 83°.5 to 83° at the points p_1 and p_2 respectively at distances of 7 and 29 m from the latter along the lava border. At the points p_3 and p_4 at the further successive distances of 15 and 13 m, the temperature was from 45°.5 to 53°.5 C. Thus, the water temperature was high and above 80° C. along the lava side for the length of about 40 metres from the old coast. At a southward distance of about 500 m along the latter from the Tobashira-hana, or the western junction of the Seto "strait" lava and the Ōsumi coast, the temperature was reduced to 20.°0 C.

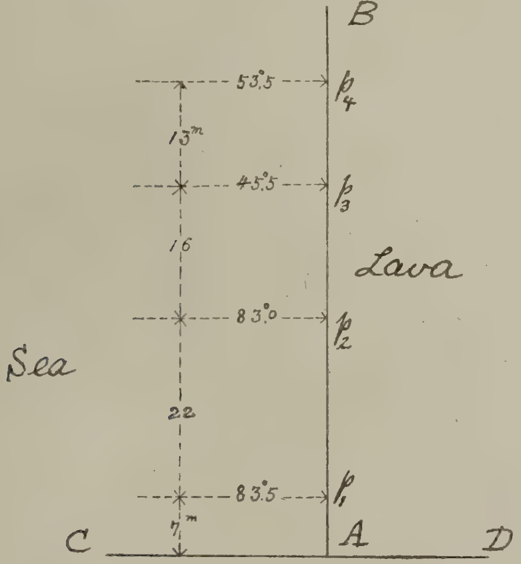

Fig. 98. Sea-water temperature along the Lava margin at the W. End of the Contact Line. CD……Coast of Ōsumi.

According to the observations described above, the slight currents of hot waters at the Seto "strait" (isthmus) took place at a low tide time simultaneously from the two opposite ends of the Contact Line and directed outwards, or away from the centre of the latter. More correctly it may be said that the currents under consideration were simply the hot waters permeating the interior heated portion of the lava mass caused to run out gradually when the sea-surface got lowered in level.

The manifestation of a very high sea-water temperature, of maximum value of 93°.7 C., at the two ends of the Seto strait contact line probably depended, amongst the others. on the notable accumulation of hot lava masses combined with the special closed nature of the small bay or inlet formed by the junction of the latter with the coast of Ōsumi. According to the observations made on April 25th, 1915, the temperature along the western margin of the "strait" (isthmus) decreased to some 50° C. already with a distance of roughly 30 m from the contact line, or former coast of Ōsumi. It is likely that the general heating effect on the sea-water at Seto was not materially different from that at those portions of the Arimra lava field, where the progressive movement of the new coast was active, and where the water indicated a temperature of nearly 60° C. in Sept. 1914.

The sea water temperatures measured at both ends of the Seto strait contact line on the three different occasions are compared in the following table :—

Date. / Place.	April 12, 1914.	Sept. 25, 1914.	April 25, 1915.
At W. end of Contact Line.	—	93°.7 C (84°.3 C)	89°.2 C (87°.2 C)
„ E. „ „	90°.0 C	88°.5 (79°.1)	82°.0 (80°.2)
In the outlet (short small canal) of Steaming Pond at E. end of Contact Line.	52°.0	68°.5 (59°.1)	57°.0 (55°.2)
At the mouth of Ushine Bay.	21°.0	—	20°.8 (19°.0)

To make a strict temperature comparison, the influence of the annual variation must be taken into account. According to Chapter VII, the mean daily sea-surface temperatures in the Kagoshima harbour, corresponding to April 12th and 25th, and Sept. 25th, were in 1910–1912 respectively 16.°5, 18.°3, and 25.°9 C; being

Sakura-jima Eruption of 1914. (Sept., 1915. F. Omori, photo.)

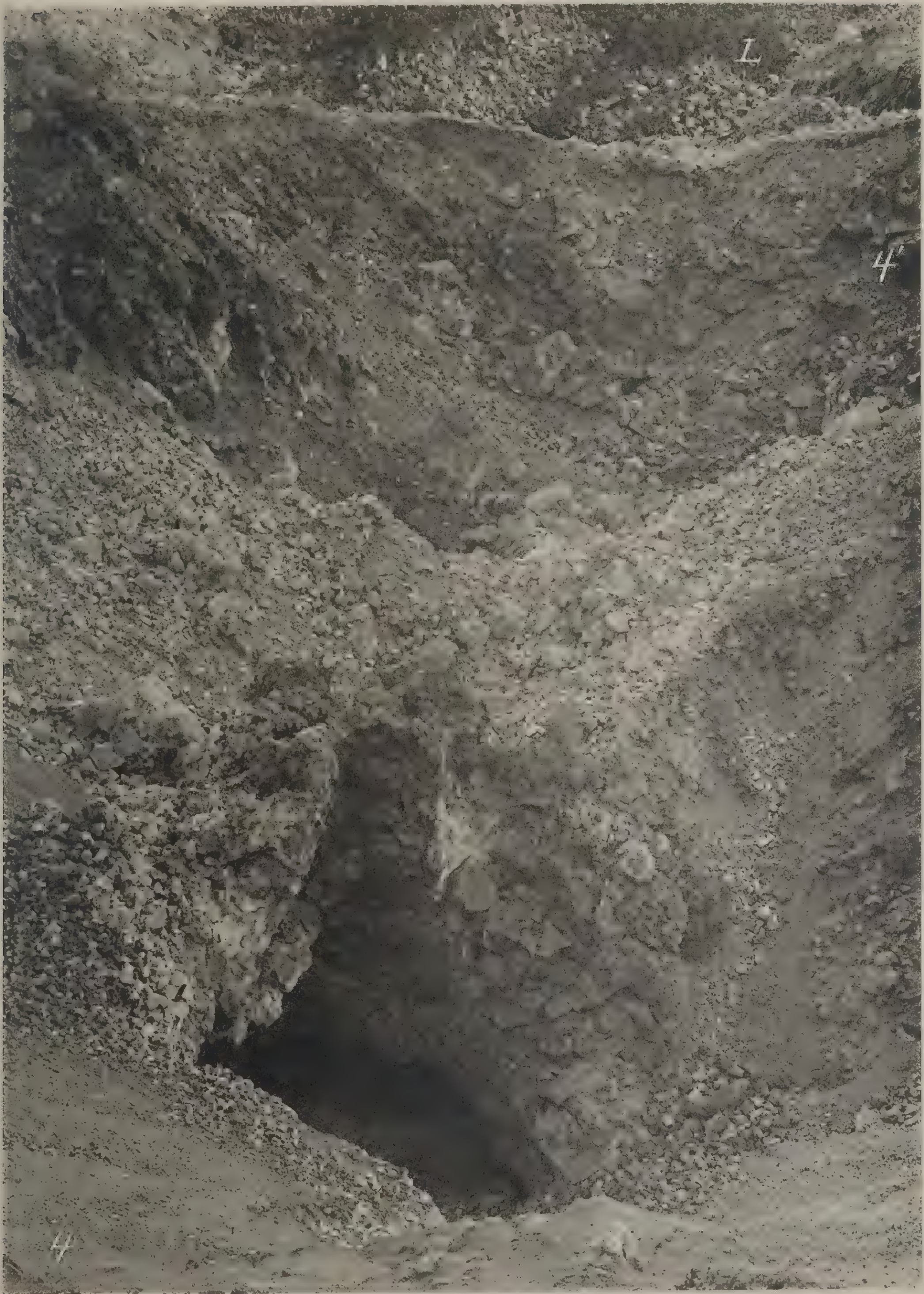

Fig. 99. Lava Vault formed at the bottom of the Eastern Craterlet No. 4.
(4), Craterlet No. 4. (4'), Craterlet No. 4'. (L), Lava field.

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Sakura-jima Eruption of 1914 : the Lava Sources on the Eastern Eruption Field.

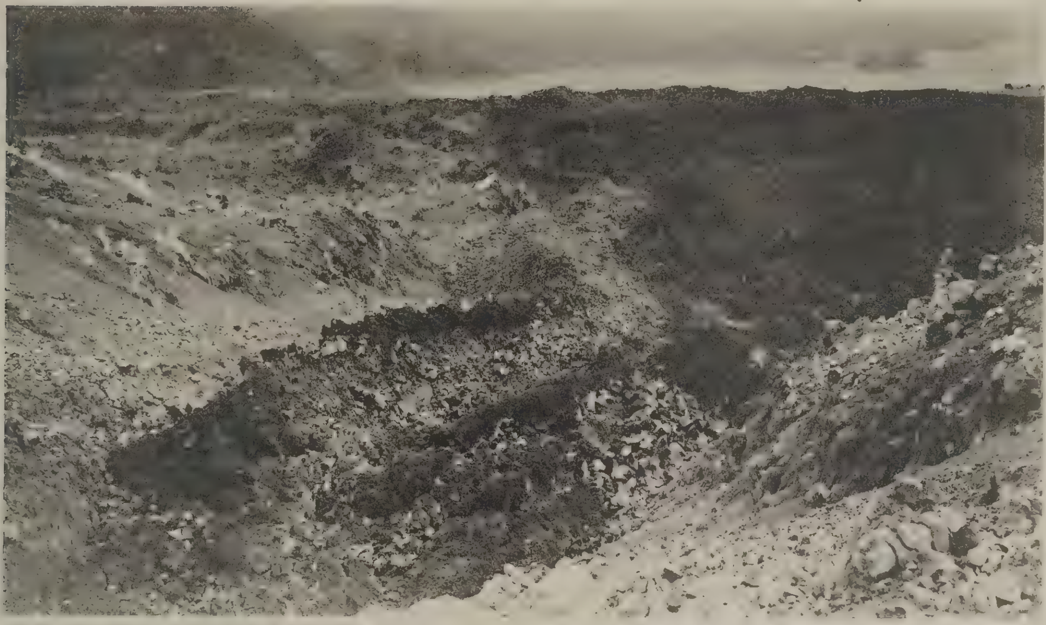

Fig. 100. U-shaped Lava Source immediately below the Craterlet No. 4′.

(April, 1915. F. Omori, photo.)

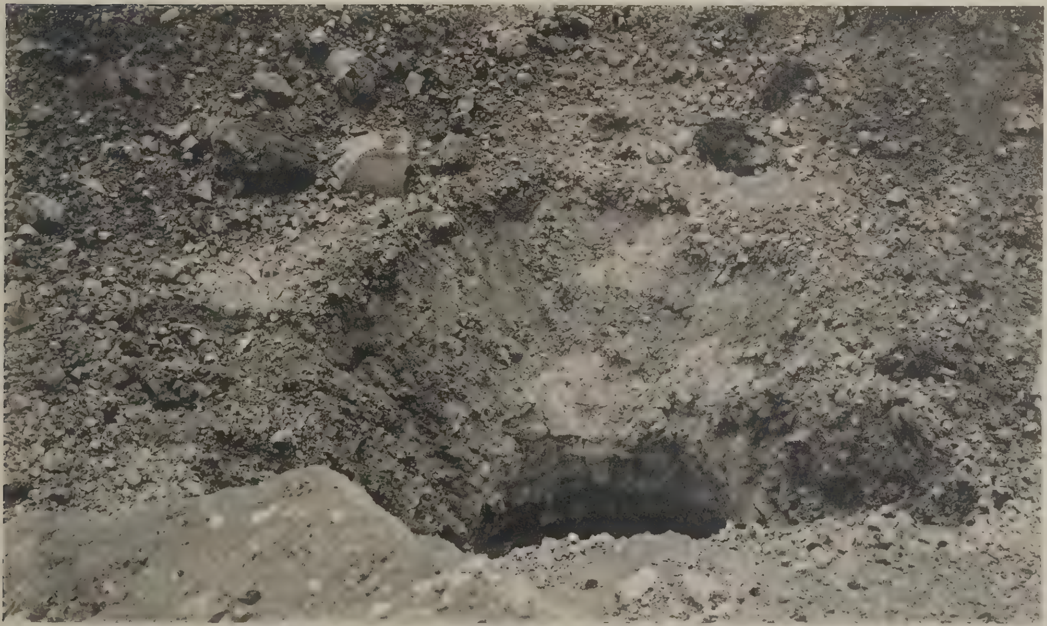

Fig. 101. A Depression Cavity at the bottom of the Eastern Branch of the Nabe-yama Eruption Crack.

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Sakura-jima Eruption of 1914. (April, 1915. F. Omori, photo)

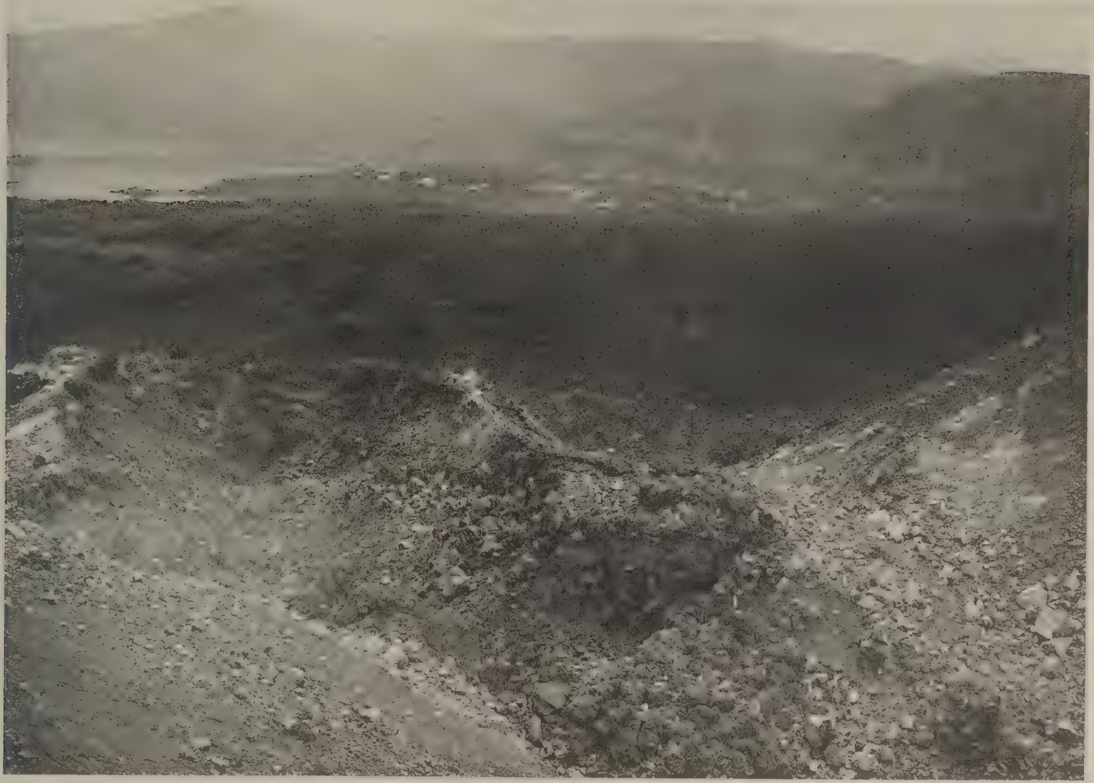

Fig. 102. The most eastern Craterlet (Lava Source) No. 7, formed at the lowest end of the Nabe-yama Eruption Crack, with the lava field extending toward the S. E.

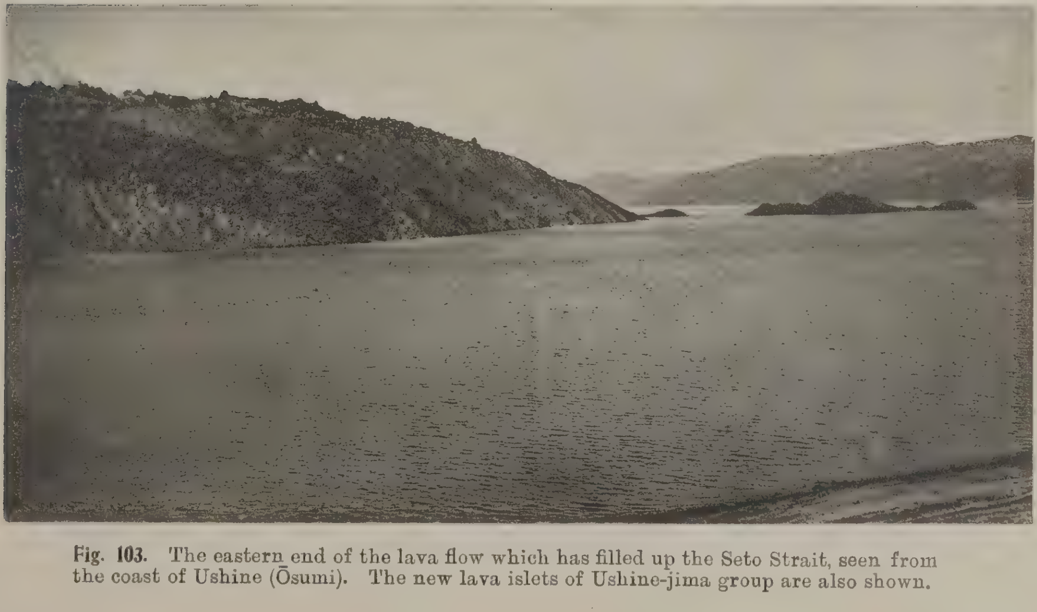

Fig. 103. The eastern end of the lava flow which has filled up the Seto Strait, seen from the coast of Ushine (Ōsumi). The new lava islets of Ushine-jima group are also shown.

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Sakura-jima Eruption of 1914 : the Western Lava Field, showing the Steaming Circle.

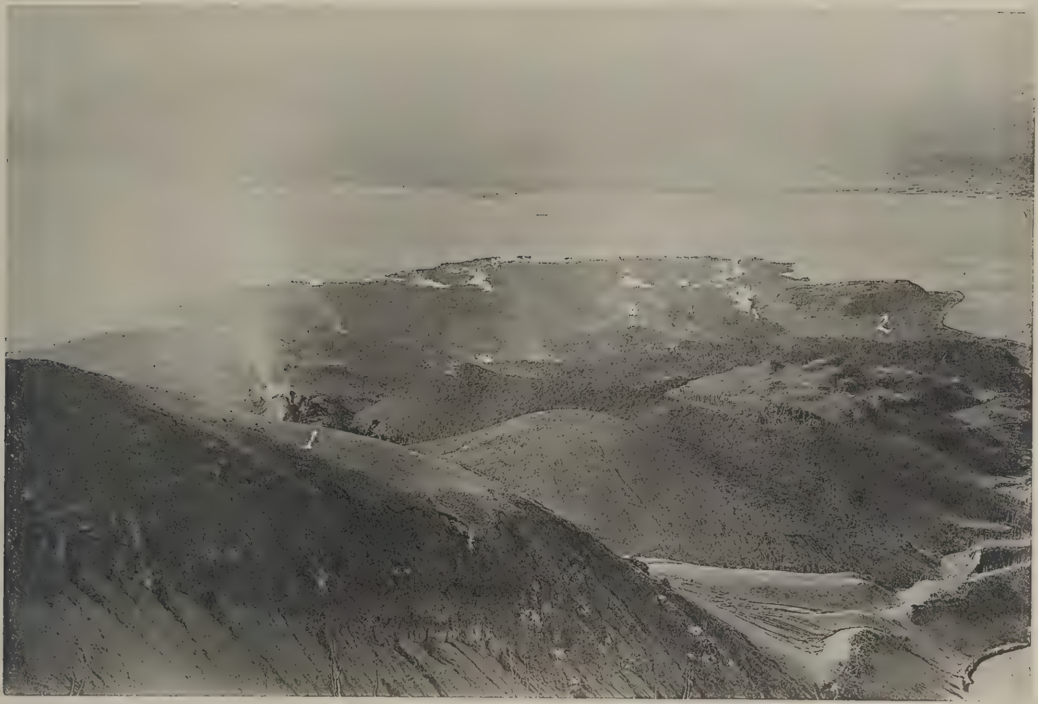

Fig. 104. General view of the lava field, taken from Kita-dake, showing the Steaming Circle at the front and the Hakamagoshi (2) and the hills above Akobaru and Koike at the right-hand side. (1), Lava Source No. 3. (Jan. 3rd, 1915. K. Ueda, photo.)

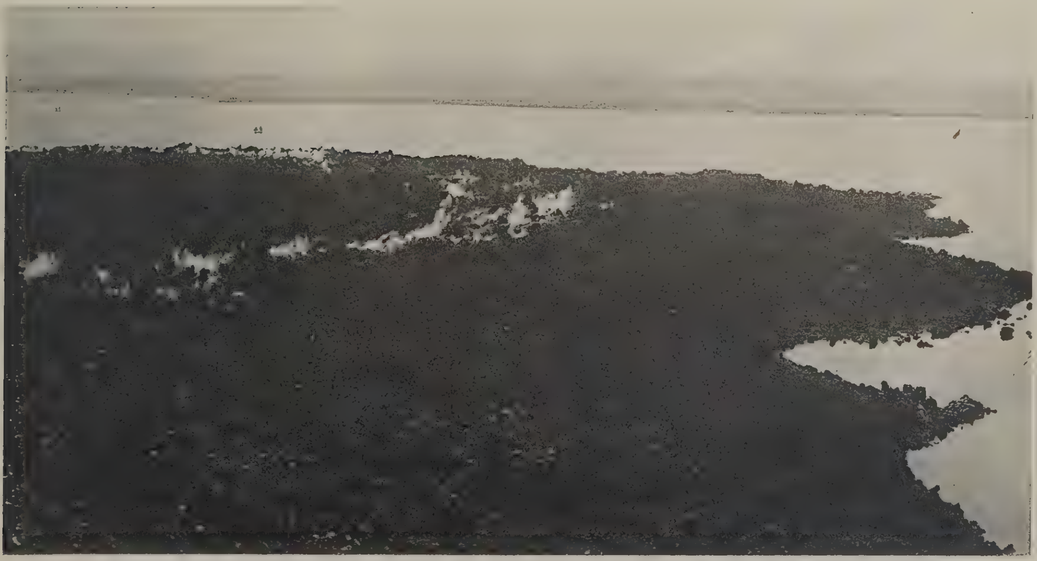

Fig. 105. The N.W. portion of the lava field, looked down from Hakamagoshi. (April, 1915. F. Omori, photo.)

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Seto Strait after the Sakura jima Eruption of 1914: (F. Omori, photo.)

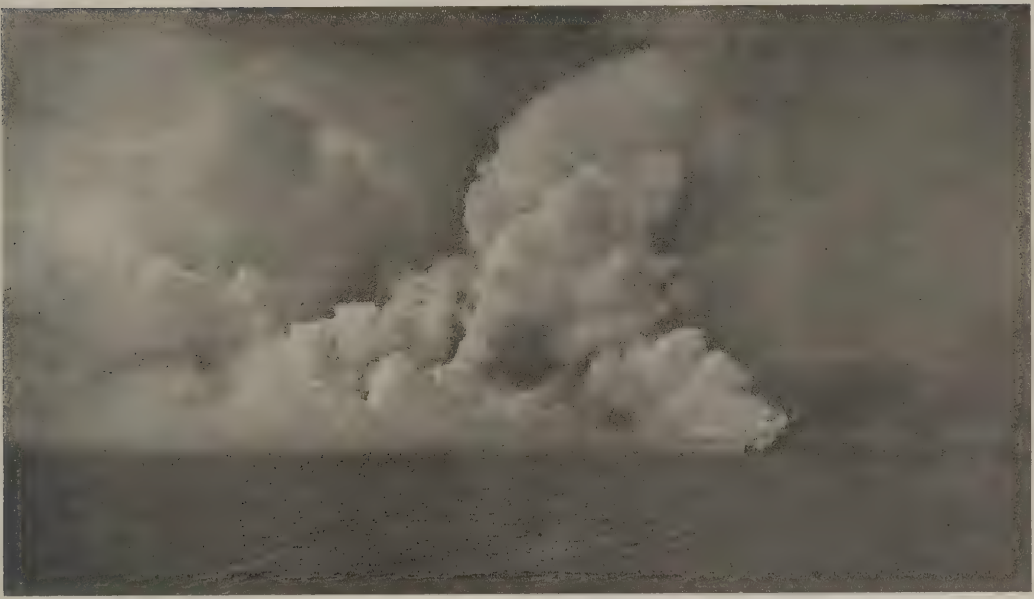

Fig. 106. Condition 4 days after the commencement of the eruption: the lava, which had flowed down into the bottom of the strait between Ōsumi (left, obscured by smokes) and Sakura-jima (right) was vigorously evaporating the water. (Jan. 16th, 1914.)

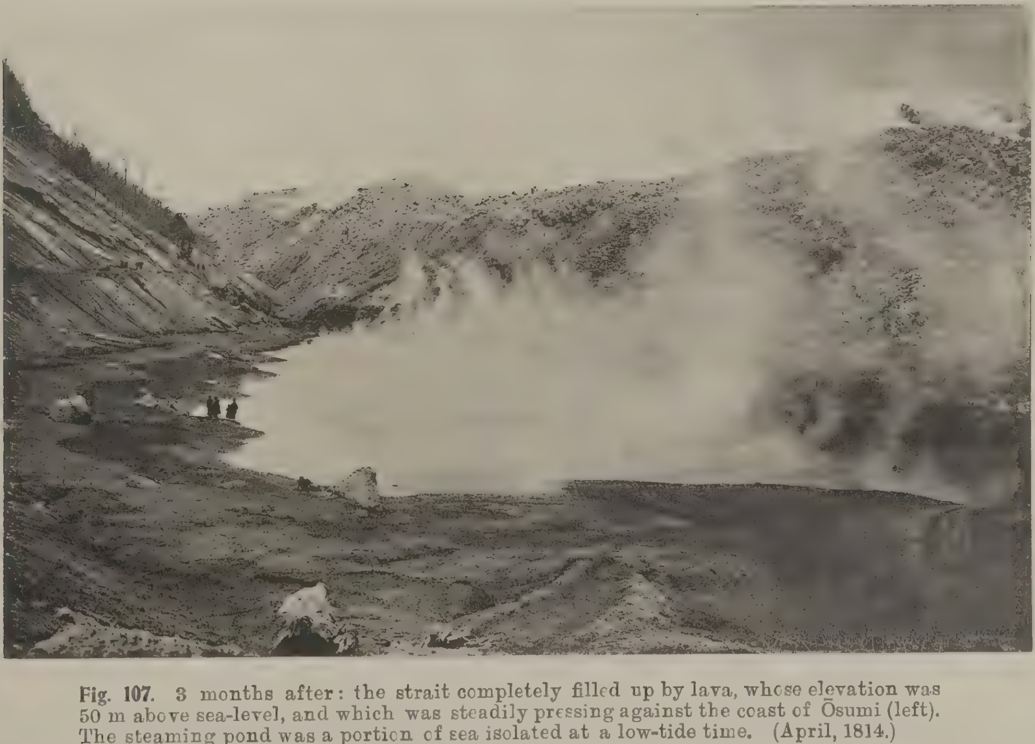

Fig. 107. 3 months after: the strait completely filled up by lava, whose elevation was 50 m above sea-level, and which was steadily pressing against the coast of Ōsumi (left). The steaming pond was a portion of sea isolated at a low-tide time. (April, 1814.)

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1.°8 and 9.°4 C higher for the two latter days than for the first. Applying provisionally these corrections to the temperature observations at Seto on Sept. 25th, 1914, and on April 25th, 1915, we get the results enclosed in brackets, which may be compared to the different quantities for April 12th, 1914. It will be seen that the corrected sea-water temperatures along the different parts of the Seto strait lava did not much vary between Sept. 1914 and April 1915, the maximum value being about 80° C. This is about 10°C lower than the corresponding temperature of 90°C for April 1914, probably indicating the decline in the heating capacity of the lava mass in question during the 5 subsequent months.

Chapter V. New Lava Islets.

40. New lava islets. (See figs. 114 to 117.) The recent eruption was not followed by a formation of new islands of more or less considerable dimensions, as was the case with the Sakura-jima catastrophe of 1779. There appeared, however, a number of isolated massive rocks or islets, off the different new promontories of the 1*st stage* lava area. These islets, of which there is one on the Arimra or S.E. side and several are at the Ushine end of the Seto strait lava, are each rather a group of rocks composed of two parallelly arranged halves, either completely or partially separated by a well cut central cleavage crack or canal, the lavas at whose two side are curved outwards. I give next a short description of these new lava islets as examined in April 1915, their positions being indicated in fig. 2 of the preceding Number of the Bulletin.

The Arimra-jima* (fig. 108) is about 12 m high and 16 m long. The central canal (AB), in the S.E.–N.W. direction, which divides the islet into two longitudinal halves, is deep and narrows towards the S.E. end, where it is 2.4 to 4.1 m in width and is filled with sea-water for the length of about 42 m. The lava forming the walls of the canal is curved down outwards, such that the islet presents a highly interesting shape, the S.W. exterior side surface (S) being composed of nearly vertical lava columns.

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* Provisional denomination. *Jima* or *shima* means island or islet.

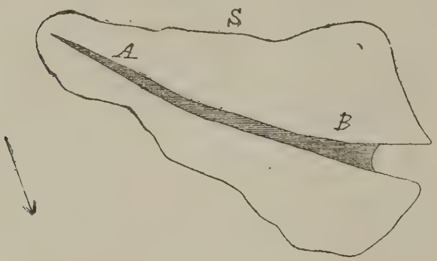

Fig. 108. Plan of Arimra-jima.
Height=12 m. Length=170 m.
AB......Cleavage canal.
(Arrow points toward N.)

The group opposite Ushine is composed of 7 new islets, of which the Oshima is the largest and is about 20 m in height and 150 m in length. (See fig. 109.) This latter is nothing other than the southern half of the lava mass, whose longitudinal canal runs in an W.N.W.–E.S.E. direction, and, forming a sort of channel, divides the Oshima completely from the 6 small islets forming the northern half arranged in a line. The walls forming the two sides of the channel are at places nearly perpendicular and are exceedingly beautiful, being composed of upright or oblique rows of slightly twisted or wavy slender bars of lava. (See fig. 115.) Where the cleavage side is not broken up into columnar pieces, we find often the lava surface thrown into

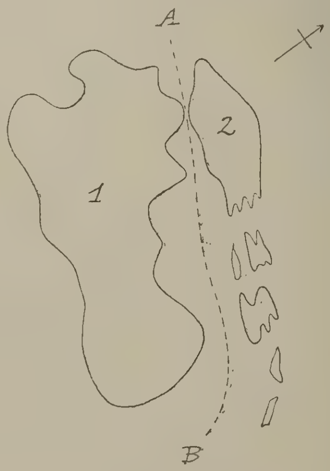

Fig. 109. Plan of new Ushine-jima lava-islet group.
Oshima (1) ...... Height=20 m. Length=150 m.
AB......Cleavage axis (canal).
(Arrow points toward N.)

curious wavy conchoidal shapes, as if formed of a number of gigantic scallop shells. (See fig. 114.)

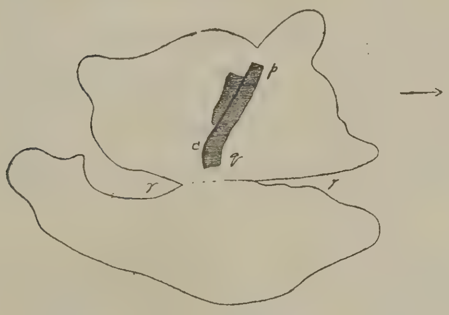

Fig. 110. Plan of Nagasaki-jima.
Height=15 m. Length=160 m.
pq......Cleavage canal. *c*......" Fence."
(Arrow points toward N.)

The Nagasaki-jima,* which is situated to the N.W. of the Ushine-jima, is 15 m in height and 160 m in length, and has a complex shape as indicated in fig. 110. It is halved by the cleavage crack *rr* in a nearly N. and S. direction, and the western portion is further divided normally by the narrow canal *pq*. The latter is composed of two parallel portions, of which the larger is about 5 m in width and 50 m in length ; the boundary between the two being composed of a thin vertical layer *c* of upright columnar lava 2 m in height, with the appearance of a fence made up of stone or wooden posts. (See fig. 116.)

41. Origin of lava islets. The different new lava islets, which already existed at the time of the present author's second visit to Sakura-jima, in April 1914, had probably been formed in the course of one or two months after the commencement of the eruption. According to fig. 81, the islet of Arimra-jima seems to have made its appearance already at the commencement of February 1914. It followed naturally that some of the islets have again been gradually buried under the advancing lava streams. Thus the picture, fig. 117, which has been taken at the end of April in 1915, represents the eastern portion of a large new lava islet 40 m in height, which had been formed off the coast of Ushine,

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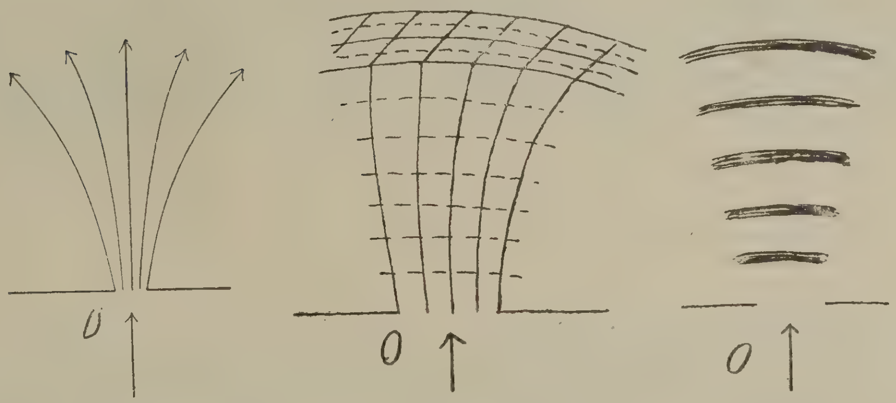
Provisional denomination.

and whose other end has already been covered up by the advancing promontory. Again, the three small islets formed some distance to the east of Yunohama, which I had seen in April 1914, subsequently disappeared under the lava field, and indicated no trace of existence at the time of my next visit one year after. It is hereby to be noted that some amount of pumice and broken pieces of straws, bamboos, sticks, etc. were found on the different lava islets. On the very top of the Ushine Oshima, at the height of 20 m above the sea surface, there were found amongst the others a thick rectangular wooden plate of 12×25×4 cm in dimensions, and a number of large pumice pieces 15 cm in maximum length, one of which had been caught and partly crushed among the broken lava blocks. On the other hand, the ordinary lava streams were strewn with no fragments of floating materials except at or near the height reached by the tides. These facts seem to indicate that the lava islets were raised from under the water, the rate of elevation having probably been quick enough to complete the formation of the *cleavage canal* while the lava mass still retained its molten or plastic condition.

At the times of my examination, there was no fumarole or solfatara on the lava islets. There was, however, on the top of the second largest among the Ushine islet-group an evidence of the existence at an earlier date of the issue of highly heated gases or vapours; the surface of the lava mass being, along certain fissures, covered by a wax-like glaze coating of dark green colour in the fashion of miniature stalactites.

The lava mass making up the islets in question is, unlike the material of the ordinary lava streams, of an uniform composition and somewhat loose and brittle throughout, and has a characteristic of being broken, inside as well as at the surface, into slender wavy rods. This is probably due to the formation of the islets in consequence of the steady upward squeezing out of the magma, under a continuous high pressure, from a narrow slit or point opened either directly at the sea bottom or at the hardened upper surface of the submerged lava stream. If the orifice O (fig. 111) be small, the principal weak lines or surfaces in the molten material pushed up will be a system of diverging curves. As the secondary weak places will be concentric surfaces formed normal to these, the lava mass will be fissured in the form of curvilinear columns as sketched in fig. 112. If the pressure with which the lava is squeezed out be very great, the whole mass would acquire some wavy arrangement in direction of the issue; giving the lava surface the scallop-like shape before mentioned.



Diagrams illustrating the formation of the stream lines, cleavage surfaces, and folds. Figs. 111 and 112 relate to the case of a small orifice, and fig. 113 to the case of a comparatively large orifice.

O......Orifice in the hardened lava crust.
Arrow indicates the direction of lava flow.

Fig. 111. Fig. 112. Fig. 113.

When the orifice (fig. 113) is comparatively large, and the lava is pushed up easily, then the molten mass will acquire foldings composed of a series of broad concentric arcs or portions of spherical surfaces, as is beautifully exhibited at portions of the ridges of the new Arimra-jima. The forms of this type were also found in a more or less clear manner at the N.W. corner of the western lava field, which projects from the S. base of Hakamagoshi into the Kagoshima channel; being the results, in this case, of the quiet oozing out of the molten lava mass, under a great horizontal pressure, from the end or side of the earlier lava streams.

Chapter VI. Volume Densities of Sakura-jima Lavas.

42. Volume density of lava.* Suppose a more or less porous piece of lava, of weight$=W$, to be immersed in water and to absorve moisture to the amount of $W'-W$. If W'' denote its weight

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* The results of some of the chemical analysis of the recent Sakura-jima ejecta carried on at the Imperial Geological Survey and the Fukuoka Mining Bureau are as follows:—

Composition.	(1). Ashes collected in Kagoshima.	(2). Lava.	(3). A dark lava piece found at the vicinity of Krokami.
$Si\,O_2$	63.39	60.59	58.72
$Al_2\,O_3$	16.75	17.77	21.83
$Fe_2\,O_3$	3.10	1.23	3.02
$Fe\,O$	4.00	5.59	6.37
$Ca\,O$	5.38	6.34	6.68
$Mg\,O$	1.43	2.39	0.20
$Na_2\,O$	3.50	3.04	1.21
$K_2\,O$	1.32	1.68	0.47
Moisture (free).	0.62	0.59	0.31
$P_2\,O$	—	0.08	
$Mn\,O$	0.03	0.24	
$Ti\,O_2$	0.57	0.71	
$S\,O_3$	—	0.23	
$P_2\,O_5$	0.20		
Soluble silica.	15.73		

(1) and (2) are quoted from Prof. D. Sato's report on the eruption of Sakura-jima given in the Bulletin of the Imp. Geol. Survey, 1914, and (3) from Dr. N. Ishikawa's account of the same volcanic disturbance given in the Sakura-jima Number of the Tokyo Geographical Society publications, 1915.

Sakura jima Eruption of 1914 : New Islets at the E. extremity of the Seto Strait Lava.
(April, 1915. F. Omori, photo.)

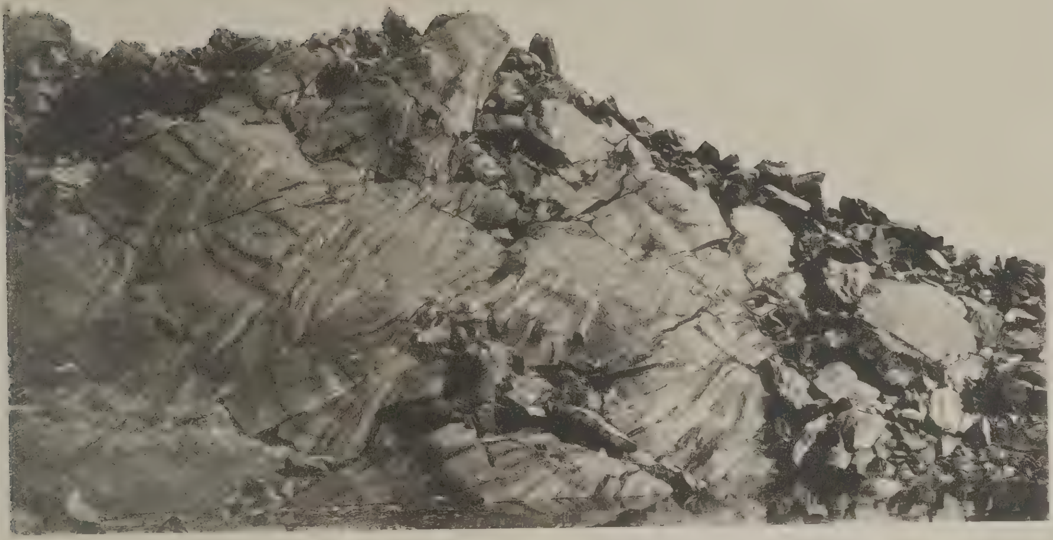

Fig. 114. "Inner" side of one of the small islets of the Ushine-jima group.

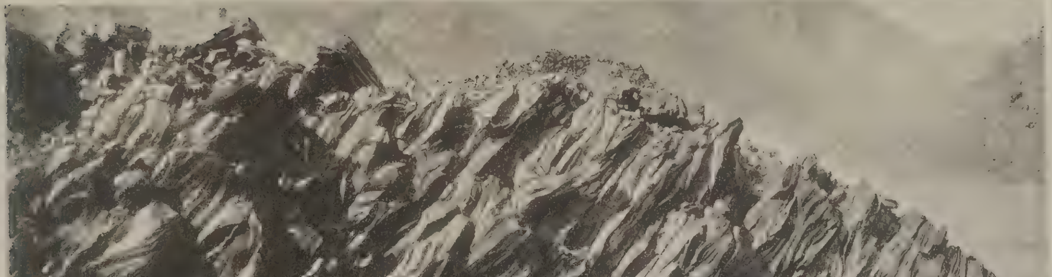

Fig. 115. "Inner" vertical side of Oshima, or the principal islet, of the Ushine-jime group.

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Sakura-jima Eruption of 1914 : New Islets at the E. extremity of the Seto Strait Lava.
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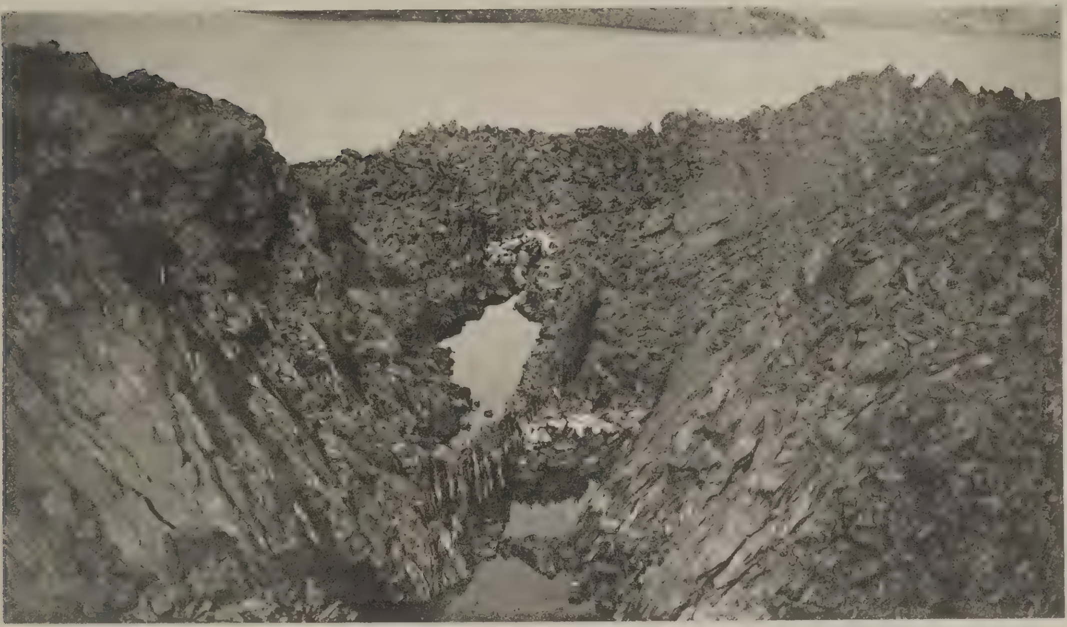

Fig. 116. The central longitudinal Cleavage Canal of Nagasaki-jima islet, showing the vertical fence-like partition wall at the middle.

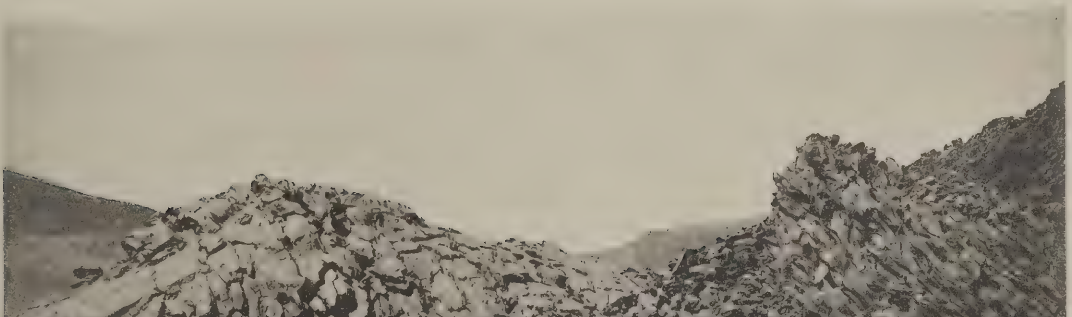

Fig. 117. Outer side of a lava islet, whose W. half has been buried under the Seto Strait lava outflow.

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in water after a sufficiently long immersion, then the *approximate* volume density of lava may be calculated as follows:—

$$\text{Volume Density} = \frac{W}{W' - W''}$$

In Table VI, at the end of this chapter, are given the volume densities calculated according to the above process of 89 specimens of lava collected at the recent eastern and western eruption fields of Sakura-jima. The water absorption was almost *nil* for some of the hard compact lava pieces, but amounted to 50% or more for some of the pumiceous specimens.

It is noteworthy that, for the new lava islets of Arimra-jima, Nagasaki-jima, and Ushine-Oshima, the density is practically constant, being mostly included between 2.62 and 2.59, with the mean value of 2.60. This uniformity of the density is what may be expected from the nature of the islets in question which have been formed by the squeezing out of the molten rock from the cracks in the upper crust of the submarine lava flows. The volume density of the mass of magma existing under the volcano may possibly be identical with the mean value of 2.6 here obtained.

For the eastern eruption field, the density of the rock specimens taken from the lava flows varied between 2.84 and 1.49 with the mean of 2.26; that of the new lava pieces projected from the different craterlets on the same side varying between 2.67 and 1.54, with the practically identical mean of 2.23. For the western eruption field, the rock specimens taken from the lava flows had the density of 2.57 to 1.06, with the mean of 2.12. These values may probably be taken as approximately representing the average densities of the lava composing the main portion of the lava streams: say, 2.3 and 2.1 respectively for the eastern and the western eruption fields. By way of comparison, it may be noted (Table VI′) that a few specimens of the old lavas forming the higher side wall of the eastern No. 1 craterlet and the top wall of Minami-dake, as well as those of the Anei (1779) and the Bummei (1475) eruptions indicated nearly the same results, the density being 2.53 to 2.16, with the mean value of 2.4.

The bombs, mostly of bread-crust appearance, had generally a low density: the mean value for the specimens collected on the eastern and the western fields being respectively 2.0 and 1.3.

The ordinary pumice pieces collected on the western eruption field had the densities of 0.90 to 0.57, with the mean of 0.75.*

On the whole, the rocks on the western eruption field, at least so far as the projected pieces and the superficial portion of the lava streams are concerned, seem to have in several instances densities slightly less than those on the eastern field. This may possibly indicate that the explosive action at the initial stage of the eruption was more violent on the western than on the eastern scene of disturbance: a supposition which apparently finds support in the facts that the first explosive outburst on the W. side took place earlier and at a higher level than that on the E. side. It seems also possible that the lava on the latter side had a somewhat deeper origin or reservoir than that on the former.

Lava of Swanose-jima and Nakano-shima. For the sake of comparison, I give in Table VI′ the values of the density of the rocks of Swanose-jima and Nakano-shima, two of the most conspicuous among the Satsuma volcanic islands. The specimens from the crater walls or old lava flows had a mean value of about 2.6, being equal to that of the rock in the new Sakura-jima lava islets. The density of the bombs was somewhat smaller, being in the mean 2.3 both for Swanose-jima and for Nakano-shima.

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* A fine specimen of very light glassy pumice was found below the lava source No. 3, near the Yokomine hill on the western field.

43. Ashes. The volume density of the Sakura-jima ashes, generally fine and ashy in colour, determined from a few samples brought to Tokyo, was as follows :—

Date of Ash-precipitation.	Place where Sample was collected.	Volume Density of Ashes in natural condition.
Jan. 17, 1914.	S. part of the city of Kagoshima.	0.86
„ 19, „	On board the steamer *Nishiki-maru*, in Kagoshima Harbour.	1.00
„ 12–22, „	N.W. base of Nabe-yama.	0.95
„ „ , „	Village of Furusato.	1.20

The following results relating to the volume density of the samples of ashes collected at different places in Sakura-jima in Jan. and Feb., 1914, are reproduced from the report of the Kagoshima Forestry Office on the effects of the eruption on forestry :—

Locality.	Weight per cubic *sun*(1)	Volume Density.	Remarks.
	momme. (2)		
At Krokami.	8.3	1.0	Mixed with sand particles of the size of rice grains.
Vicinity of Krokami.	8.4	1.0	„
On Nabe-yama.	10.0	1.2	„
Gongen-yama, (near Nabe-yama.)	9.3	1.1	„
Wariishi-zaki.	9.3	1.1	Mixing no sand particles.
Vicinity of Yunohama.	7.6	0.9	With a comparatively strong acidity, and mixing pumice fragments of the size of poppy seed.
Above Yunohama.	7.4	0.9	Mixing black sands of the size of poppy seeds.
Tobashira-hana (Sakkabira).	7.4	0.9	„
Vicinity of Arimra.	5.9	0.7	Mixing pumice particles of the size of poppy seeds.
Coast of Ushine.	8.9	1.1	Mixing pumice particles of the size of rice grains.

(1) 1 *sun* = 3.03 cm = 0.1 foot very nearly.   (2) 1 *momme* = 3.75 grams.

According to the investigations made at the Kagoshima Agricultural Experiments Station, the real density of the ashes precipitated in Kagoshima on Jan. 19th, 1914, had the mean value of 2.63, which is practically identical with the volume density of the compact lavas forming the new islets considered in § 42. The volume density of, and the amount of the moisture contained in, the ashes were as follows :—

Date of Ash-precipitation. (Jan. 1914.)	Locality of sample collection.	Ashes.	Amount of Moisture contained in Ashes.	Volume Density of Ashes (freed of moisture).
19th.	Kagoshima City.	Fine and ashy white.	—	0.81 (coarse). 1.02 (fine).
15th.	Nishi-Kokbu.	Ashy white, mixed with some coarse particles.	10.77	0.86
14th.	Iwakawa.	Mixed with dark pumice particles.	12.71	0.89
29th.	Eastern part of Sakura-jima.	Fine and ashy white.	6.34	0.95

Comparing together the different results above noted, the volume density of the Sakura-jima ashes in the original moisture-containing condition is included between 0.7 and 1.2, with the mean value of 1.00. The new ash-layer is thus of the same weight as water, being some 10 to 12 times heavier than newly fallen snow. The volume density of the ashes deprived of its moisture is between 0.81 and 1.02, with the mean value of 0.91.

According to the examinations made at the Kagoshima Agricultural Experiments Station, the percentage amounts at different places within the Kagoshima prefecture of the solid particles in the Sakura-jima ashes of diameter under 0.5 mm, over 1.0 mm, and over 4.0 mm were as follows :—

TABLE. V. Total Percentage Amount of Ash-particles of different Diameters.

地名（村，字）	Locality.	Diameter < 0.5 mm.
上荒田（鹿兒島市外）	Kami-Arada (Kagoshima).	99.8
赤生原（櫻島西端）	Akobaru (Sakura-jima).	96.0
白濱 （ ,, 北部）	Shirahama ,,	97.5
湯之 （ ,, 南西部）	Yuno ,,	98.4
古里 （ ,, 南部）	Furusato ,,	91.5
西襲山西光寺	Nishi-Soyama. (Aira county, Ōsumi).	92.0
國分上小川	Kokbu. ,,	96.9
山田，下名（姶良郡）	Yamada ,,	97.0
蒲生，上久德（ ,, ）	Gamo ,,	98.5
溝邊，有川（ ,, ）	Mizobe ,,	99.0
橫川，中野（ ,, ）	Yokogawa ,,	99.5
栗野，木場（ ,, ）	Krino ,,	99.5
吉松，川西（ ,, ）	Yoshimatsu ,,	100.0
財部，南俣（噌唹郡）	Takarabe (Sō county, Ōsumi).	96.5
鹿屋，秡川（肝屬郡）	Kanoya (Kimotsuki county, Ōsumi).	99.9
高隈，下高隈	Takakma ,,	97.5
垂水，田神	Tarumizu ,,	97.0
高隈，麓	Takakma Fumoto ,,	96.0
花岡，木谷	Hanaoka ,,	100.0
新城，新城	Shinjo ,,	100.0
垂水，柊原	Tarumizu, Hiiragibaru ,,	97.0

地名（村，字）	Locality.	Diameter > 1.0 mm	Diameter > 4.0 mm
藤野（櫻島西北部）	Fujino (Sakura-jima).	69.5	3.50
西道（ ,, ）	Saido ,,	30.0	—
福山，牧ノ原	Fukuyama.	12.5	—
西國分	Nishi Kokbu.	20.0	—
西志布志，伊崎田	Nishi-Shibshi.	15.6	1.7

TABLE V. (*Continued.*)

地名（村，字）	Locality.	Diameter > 1.0 mm	Diameter > 4.0 mm
東國分，小村	Higashi Kokbu.	11.0	—
恒吉，長汳	Tsuneyoshi.	10.0	—
牛根，二川	Ushine.	27.0	12.0
,,	,,	38.8	6.0
,,	,,	63.0	14.0
垂水，脇登	Tarumizu.	29.5	1.0

Referring to the map indicating the amount of the precipitation of the ashes in the southern part of Kyushu (fig. 33, in the preceding Number of the Bulletin), we see that the districts, where the constituents of the Sakura-jima ejecta of diameter over 1.0 mm was greater than 10%, approximately coincides with the area enclosed by the curve of 3 *sun* (= 9 cm) ash-accumulation. Again the zone, in which the amount of the particles of the size greater than 4 mm was over 6%, practically coincides with that enclosed by the curve of 30 *sun* (= 0.9 metre) ash-accumulation. At the E. and N. extremities of the 5 *sun* (= 15 cm) accumulation area, the particles of diameter greater than 4 mm were respectively 0.5 and 1.7% in amount.

TABLE VI. Volume Density of the new Sakura-jima Lavas.

Date of sample collection.	Locality.	Volume Density.
	(I) New Lava Islets.	
April 25, 1915.	Arimra-jima.	2.62 2.61 2.60 2.59 2.61

TABLE VI. *(Continued.)*

Date of sample collection.	Locality.	Volume Density.
May 5, 1915.	Ushine-Oshima.	2.60 2.59 2.36
,, ,,	Nagasaki-jima.	2.60 2.07
	(II) Eastern Lava Flows.	
Jan. 24, 1914.	At Yubama (Yunohama) beach.	2.12
,, ,,		1.95
Sept. 27, ,,		2.03
,, ,,		2.54
,, ,,		2.51
,, ,,		2.62
April 21, 1915.		2.60
,, ,,		2.60
,, ,,		2.61
,, ,,		1.93
,, 25, ,,		2.16
April 12, 1914.	Seto " Strait " Lava.	2.37
Sept. 29, ,,		2.07
,, ,,		1.66
April 25, 1915.		2.51
Sept. 29, 1914.	Below No. 1 Craterlet.	1.84
Jan. 23, 1914.	Vicinity of Krokami.	1.92
,, ,,		1.49
Oct. 2, ,,		2.84
,, ,,		2.55

TABLE VI. (*Continued.*

Date of sample collection.	Locality.	Volume Density.
Oct. 2, 1914.	Vicinity of Krokami.	2.46
,, ,,		2.28
(**III**) Lava Pieces newly projected from the Eastern Craterlets.		
April 9, 1914.	Vicinity of No. 1 Craterlet.	2.57
,, ,,		2.25
,, ,,		2.18
,, ,,		2.27
,, ,,		2.40
,, ,,		1.91
Sept. 27, ,,		2.46
,, ,,		2.28
,, ,,		2.18
,, ,,		1.67
April 22, 1915.	Vicinity of No. 2 Craterlet.	2.08
,, 23, ,,	,, No. 3 ,,	2.19
,, ,, ,,	,, No. 4′ ,,	2.67
Jan. 23, 1914.	Nabe-yama : N. base.	2.16
April 9, ,,	,, : N.W. top.	2.24
May 4, 1915.	,, : S.E. slope.	2.65
,, ,,	,, ,,	2.42
,, ,,	,, ,,	1.62
,, ,,	,, : N. base.	1.54
Sept. 22, ,,	,, : S.E. top.	2.55
,, ,,	,, ,,	2.44
(**IV**) Western Lava Flows.		
Jan. 18, 1914.	Vicinity of Yokoyama.	1.06
,, 22, ,,	Near Hakamagoshi.	1.63

TABLE VI. *(Continued.)*

Date of sample collection.	Locality.	Volume Density.
Jan. 22, 1914.	Above Akobaru. (Specimen taken from a large lava block.)	2.19
April 8, 1915.	"	2.51
" "	"	2.48
May 6, "	Tora-zaki, or N.W. corner of the lava field.	2.45
" "	"	2.27
Sept. 30, 1915.	Vicinity of the former Karasu-jima.	2.57
		2.48
		2.47
		2.48
		2.39
		2.32
		2.34
		2.32
		2.29
		2.26
		2.24
		2.09
		1.70
		1.48
		1.49
		1.32
(**V**) Lava Pieces projected from the Western Craterlets.		
April 8, 1915.	At Bottom of No. 1 Craterlet.	2.16
		2.02
(**VI**) Bombs from the Eastern Craterlets.		
Jan. 24, 1914.	At the N.W. foot of Nabe-yama.	2.81
April 23, 1915.	Between Craterlets Nos. 3 and 4.	1.94

TABLE VI. *(Continued.)*

Date of sample collection.	Locality.	Volume Density.
April 23, 1915.	Between Craterlets Nos. 2 and 3.	1.71
„ 25, „	„ „ „	1.58
	(VII) Bombs from the Western Craterlets.	
April 9, 1914.	Near Akobaru.	1.34
		1.29
		1.19
	(VIII) Pumice.	
Jan. 18, 1914.	Near Koike.	0.90
		0.85
		0.66
		0.57

TABLE VI'. Volume Densities of old Sakura-jima Lavas.

Locality.	Volume Density.
W. side wall of Eastern No. 1 Craterlet.	2.53
	2.45
Anei (1779) Lava, at Furusato.	2.47
	2.34
Bummei (1475) Lava, forming the wall of an old craterlet, near Yuno.	2.49
Minami-dake Top.	2.16
	2.16

TABLE VII. Volume Density of Lavas and Bombs of Swanose-jima and Nakano-shima.

Lava.		Volume Density of Bombs.
Locality.	Volume Density.	
Swanose-jima.		
Lava pieces recently projected, found at the vicinity of Trigonometrical Point.	2.76	2.57
	2.76	2.44
	2.69	2.43
	2.54	2.32
1813 (文化十年) lava flow, at Akazome-ura (赤染浦).	2.58	2.37
	2.27	1.75
Lava forming the wall of 1813 (文化十年) craterlet.	2.67	2.31 (mean.)
	2.56	
	2.60 (mean.)	
Nakano-shima.		
Lava forming the wall of the old crater.	2.60	2.67
	2.56	2.60
	2.58 (mean.)	2.46
		2.32
		2.10
		1.67
		2.30 (mean.)

Chapter VII. Heating Effect of the Submerged Lava Flows on the Sea Water.

44. Surface sea-water temperature before the eruption. The Kagoshima meteorological observatory carried on, from 1910 to 1912, the observation of the surface sea-water temperature at the quay of the Kagoshima harbour, the measurement having been made once every day at 10 a.m. The 5-daily mean values during these three years are given in Table IX, from which it will be seen that the absolutely highest and lowest temperatures were respectively 29°.8 (in Aug. 1912) and 14°.4 C (in Feb. 1911 and 1912).

45. Annual variation of surface sea-water temperature before the eruption. Table VIII, which has been compiled from Table IX, gives the mean monthly values of the sea-water temperature at the quay of the Kagoshima harbour, for the years 1910–1912. The mean high temperatures of 27°.2, 28°.3, and 26°.6 C occurred respectively in July, August, and September, and the mean lowest temperatures of 15°.3, 15°.0, and 15°.3 C respectively in January, February, and March ; the extreme difference being 13°.3 C. The changes due to the annual variation must of course be taken account of in the consideration of the temperature increase of the sea-water around Sakura-jima caused by the inflow of the recent lava streams.

Table VIII. Mean Monthly Temperature of the Surface Sea-Water in Kagoshima Harbour, 1910–1912.

Year. / Month.	1910	1911	1912	Mean.	Year. / Month.	1910	1911	1912	Mean.
I	—	15°.3 C	15°.3 C	15°.3 C	VII	27.°3 C	27°.1 C	27°.3 C	27°.2 C
II	—	15°.0	14°.9	15°.0	VIII	27°.9	27°.5	29°.6	28°.3
III	—	15°.6	15°.0	15°.3	IX	25°.9	27°.1	26°.8	26°.6
IV	17°.2 C	18°.2	16°.4	17°.3	X	23°.4	23°.2	23°.3	23°.3
V	20°.4	19°.6	19°.8	19°.9	XI	20°.8	19°.8	20°.7	20°.4
VI	23°.0	22°.9	23°.7	23°.2	XII	17°.2	17°.0	18°.3	17°.5

TABLE IX. 5-daily Mean Temperature of the Surface Sea-water in Kagoshima Harbour, 1910–1912.

Date.		1910	1911	1912	Mean.
I	1– 5	—	16°.1 C	15°.9 C	16°.0 C
	6–10	—	15.6	15.8	15.7
	11–15	—	15.3	15.4	15.3
	16–20	—	14.8	15.2	15.0
	21–25	—	15.1	15.4	15.2
	26–30	—	15.0	14.5	14.7
II	31– 4	—	15.3	14.4	14.8
	5– 9	—	14.9	14.9	14.9
	10–14	—	15.4	15.2	15.3
	15–19	—	15.6	14.8	15.2
	20–24	—	14.4	14.8	14.6
	25– 1	—	14.9	15.2	15.0
III	2– 6	—	14.8	15.3	15 0
	7–11	—	15.2	15.1	15.1
	12–16	—	15.7	14.8	15.2
	17–21	—	15.6	14.7	15.1
	22–26	—	15.6	14.6	15.1
	27–31	—	17.2	15.5	16.3
IV	1– 5	—	17.5	15.0	1.62
	6–10	15°.9 C	18.1	14.9	16.3
	11–15	16.5	18.4	15.3	16.7
	16–20	17.0	18.0	16.9	17.3
	21–25	18.3	18.6	17.8	18.2
	26–30	18.2	18.7	18.7	18.5
V	1– 5	17.7	18.1	18.8	18.2
	6–10	20.5	18.4	19.3	19.4
	11–15	19.9	19.8	19.3	19.7
	16–20	20.5	19.6	20.6	20.2
V	21–25	21°.6 C	20°.6 C	20°.1 C	20°.8 C
	26–30	21.7	21.1	20.4	21.1
VI	31– 4	22.9	21.4	22.0	22.1
	5– 9	22.3	22.5	22.5	22.4
	10–14	21.7	22.5	23.9	22.4
	15–19	23.1	23.3	—	23.2
	20–24	23.6	22.6	27.5	24.6
	25–29	24.2	23.9	24.3	24.1
	30– 4	25.3	23.5	25.5	24.8
VII	5– 9	25.8	26.0	25.8	25.9
	10–14	27.0	27.3	26.1	26.8
	15–19	28.2	28.1	27.8	28.0
	20–24	28.6	28.9	28.2	28.6
	25–29	27.8	27.8	27.6	27.7
	30– 3	28.5	27.5	29.2	28.4
VIII	4– 8	28.1	27.7	29.7	28.5
	9–13	27.6	27.3	29.6	28.2
	14–18	27.5	26.9	29.6	28.0
	19–23	27.4	27.8	29.8	28.3
	24–28	28.1	27 8	29.5	28.5
	29– 2	29.1	27.3	29.1	28.5
IX	3– 7	27.7	27.6	29.2	28.2
	8–12	27.1	27.5	28.2	27.6
	13–17	27.4	27.3	26.1	26.9
	18–22	26.0	27.0	25.9	26.3
	23–27	26.0	26.5	25.3	25.9
	28– 2	25.5	26.2	23.8	25.2

Table IX. (*Continued.*)

Date.		1910	1911	1912	Mean.
X	3–7	24.°6 C	24.°9 C	24.°2 C	24.°6 C
	8–12	23.7	23.7	23.4	23.6
	13–1	23.3	23.2	23.1	23.2
	18–22	22.9	22.7	22.9	22.8
	23–27	22.6	21.8	22.9	22.4
	28–1	22.3	21.3	22.7	22.1
XI	2–6	22.0	21.2	22.4	21.9
	7–11	21.3	20.1	21.6	21.0
	12–16	21.4	20.3	21.0	20.9
XI	17–21	20.°3 C	19.°8 C	19.°8 C	20.°0 C
	22–26	20.2	18.6	19.2	19.3
	27–1	19.4	18.3	19.3	19.0
XII	2–6	18.2	18.2	19.0	18.5
	7–11	17.6	17.6	18.4	17.9
	12–16	17.1	16.8	18.5	17.5
	17–21	16.8	16.7	18.3	17.3
	22–26	16.4	16.3	18.3	17.0
	27–31	16.4	15.9	17.5	16.6

46. Surface sea-water temperature in and outside the harbour of Kagoshima. From the comparative list in Table X based on my observations carried on in 1914 and 1915, it will be seen that, so far as the measurements in Jan., April, May, Sept., and Oct. are concerned, the surface sea-water temperature at the quay was nearly equal to those in and just outside the harbour, in Kagoshima Strait, and along the N.W. coast of Sakura-jima.

Table X. Comparison of Surface Sea-Water Temperatures in and out of the Kagoshima Harbour.

Date. \ Place.	Quay.	Within the Harbour.	Without the Harbour.	In Kagoshima Strait.	Coast of Take and Fujino. (Sakura-jima.)
Jan. 16th, 1914.	18.°0 C				
„ 18th, „	—	—	—	—	16.°7 C
„ 23rd, „	—	—	—	—	17.2
April 8th, „	16.5	—	17.°0 C	16.°8 C*	—
„ 9th, „	16.4	—	—	16.5	—
„ 11th „	—	16.°6 C*	17.0	16.6*	16.6*
„ 12th, „	—	16.5	16.5*	17.2	—

TABLE X. *(Continued.)*

Place. Date.	Quay.	Within the Harbour.	Without the Harbour.	In Kagoshima Strait.	Coast of Take and Fujino. (Sakura-jima.)
April 15th, 1914.	—	—	16°.7 C	16°.7 C	—
„ 17th, „	16°.5 C	—	—	16.4	—
Sept. 23rd, „	—	26°.0* C	25°.6	26.1*	—
Oct. 1st, „	—	24.5	25.0	25.0*	24°.5 C
„ 3rd, „	—	24.7	24.8	24.9*	25.0
April 29th, 1915.	—	—	—	17.3*	—
„ 30th, „	—	17.4*	16.6*	16.6*	—
May 5th, „	—	17.7	18.2	18.5	18.8
„ 6th, „	—	17.1*	17.6*	17.6*	—

(*)......Mean of two or more observations.

The tables given at the end of this Chapter contain the results of the measurements of the surface sea-water temperature, which I have carried on around Sakura-jima on the different occasions after the eruption of 1914.

47. Surface sea-water temperature in Kagoshima harbour before and after the eruption. In Table XI are given the sea-water temperatures measured at the quay of, or in, the harbour of Kagoshima after the eruption of 1914; the figures enclosed in brackets being the corresponding temperatures taken from the list (Table IX) of the 5-daily means observed at the quay during 1910, 1911, and 1912. It seems that the water in the harbour was, in the latter half of January 1914, some 1°½ or 2°C warmer than in the similar epoch in the 3 previous years. The water temperature during April, Sept., and Oct., in 1914, was almost exactly identical to that in the ordinary years. Again, in April and May, 1915, there was no indication whatever of any unusual heating effect on the harbour water to be traced to the eruption. It is superflous to remark that the indication of high values of the water temperature in Sept. 1914 was due to the annual variation of the latter considered in § 45.

TABLE XI. Comparison of Surface Sea-water Temperatures in Kagoshima Harbour before and after the Eruption of 1914.
(The mean temperature in 1910-12 is enclosed in brackets.)

Day.	1914.				1915.	
	Jan.	April.	Sept.	Oct.	April.	May.
1				24.°5 C		
2				(24.9)		
3				24.7		
4						
5						17.°7 C (18.°8)
6						17.°4*
7						
8		16.°5 C (16.°3)				
9		16.4				
10						
11		16.6*				
12		16.5 (16.°5)				
13						
14						
15		16.7 (17.°0)				
16	18.°0 C (15.°2)					
17		16.5 (17.°2)				
18	16.7* (15.°0)					
19						
20						
21						
22						
23	17.2 (15.°2)		26.°0* (26.°1)			
24						
25						
26						
27						
28						
29					17.°3* (18.°3)	
30					17.4*	
31		—	—		—	

(*), Mean deduced from two or more measurements.

48. Sea water temperature below the surface. The following table gives the results of the measurement of the sea water temperature at and below the surface made by the author in conjunction with Mr. Y. Katsuno, of the Kagoshima meteorological observatory, with a deep-sea thermometer, on April 15th, 1914.

Place of Observation.	Water Depth.	Temperature at Bottom.	Corresponding Surface Temperature.
(i) Middle of Kagoshima Strait.	16 fathoms.	18°.0 C	17°.8 C
(ii) Kagoshima Strait, ½ km from the lava coast, near the new Karasu-jima Bay.	28	18°.5	20°.0 ; 20°.4
(iii) Near the lava coast, in the new Karasu-jima Bay.	27½	23°.0	24°.5 ; 26°.0 ; 27°.0 ; 30°.5
(iv) Near to (iii).	1	19°.5	21°.0
(v) 100 m off the new lava coast of Arimra, where gases bubbled up from the submerged lava mass.	18	18°.5	18°.7

In (i), (ii), and (v), the water temperature at the bottom, 16 to 28 fathoms in depth, was materially the same as that at the surface; probably due in the first two cases, to the existence of sufficient tidal currents, and in the last to the convection movements among the sea water. In (iii), where the heating effect of the lavas was marked, the bottom temperature was of course much lower than the surface one; the difference being already clear at the depth of 1 fathom as in (iv). On April 12th, 1914, the sea surface in the shallow Yubama (Yunohama) bay, close to the Arimra lava terminus, was high in temperature and sufficiently warm for the swimmer, who could, however, feel with feet much colder water below.

49. Heating of the sea water due to the eastern lava field. As described in § 39, the surface sea-water temperature at the two ends of the contact line of the Seto "strait" (isthmus) lava was high, the difference over that in Kagoshima Strait being approximately 73.°5 C in April 1914, and 62°.5 to 71°.6 C in Sept. 1914 and April 1915, as follows:—

Date.	Temperature at E. end of Seto Contact Line.	Temperature at W. end of Seto Contact Line.
April 12th, 1914.	73°.5 C + T_0	—
Sept. 25th, "	62°.5 + T_0	66°.4 C + T_0
April 25th, 1915.	64°.7 + T_0	71°.6 + T_0

(T_0 = Corresponding temperature of the surface sea-water in Kagoshima Strait.)

The temperature excess for the Seto strait, while still unclosed, on Jan. 23rd, 1914, was 32° C; and that for the Ushine bay, or the portion of the sea enclosed between the Seto "strait" lava stream and the Ushine coast of Ōsumi, was brought down to 8°.1 to 10°.5 in April 1914 and May 1915, although spots of higher temperatures existed quite close to some of the new lava islets. From these facts, we can easily suppose that the area of the marked increase in the water temperature must have been limited in extension, and, as will be seen from Table XII (i), the sea water around the north-western coast of Sakura-jima was practically uniform in temperature from Kagoshima to Komen and Uranomae, in April 1914; to Ōmoe-zaki and Krokami or Nagasaki-hana, in Oct. 1914—May 1915; the radial distances from Seto to the limit of the constant temperature being in these two epochs respectively only about 5½ and 3 (or even 1½) km. On Jan. 23rd and April 11th, 1914, the amounts of the increase of the temperature at the neighbourhood of Moe-jima, Ōmoe-zaki, and Krokami, over that at the Kagoshima strait were 2°.3 and 1°.1 to 3°.0 respectively.

Turning our attention to the sea around the S.W. and S. coast of Sakura-jima, we see, from Table XII (ii), that on Jan. 24th, 1914, the temperature off the Cape Moe-zaki was 12° C higher than in Kagoshima Strait. In April 1914 to April 1915, the difference was reduced to 0°.8 to 2°.1 C; while the corresponding quantity for the sea-water off Kwannon-zaki and Furusato during the same time interval, was only slightly larger, namely, 1°.0 to 3°.8 C. According to the observations on April 29th, 1915, the temperature was practically uniform throughout the whole sea route between Furusato and Kagoshima. Again, the temperature along the S.W. coast of Sakkabira (Ōsumi) was, in April 1914, from 14°.5 to 19°.3 C higher than that in Kagoshima Strait; this difference being reduced in April 1915 to only about 2°.0. With regard to the temperature distribution off the S. coast of Sakura-jima, the islet of Oko-jima and the cape of Moe-zaki seem to have formed the boundary of the area of warmer water, its radial distance from the Arimra lavas being about 5 to 5½ km.

On the whole, the heating effect of the lavas in question was more powerful and lasting than those on the western side, owing to their long-sustained activity, progress, and remarkable submarine extension. The influence of the latter circumstance can well be seen from the observations on Sept. 25th, 1914, illustrated in fig. 118. Thus, the temperature, which was on that day 27°.3 to 27°.9 at the coast between Tarumizu and Arazaki, was increased to 29°.7 at a distance of ½ km to the S.W. of the islet of Eno-shima, this locality being quite close to the southern end of the submerged lava streams. Thence, across over the latter, the temperature was gradually increased to 57° or 57°.5 along the lava coast itself.

In fig. 118 is indicated the approximate areas for April, 1914, in which the temperature of the surface sea-water was decidedly higher, say, by 2° or so, than that in Kagoshima Strait; these forming a sort of semi-circular ring about the south-eastern half of Sakura-jima, of maximum distance of 3 to 3½ km from the original coast of Arimra. besides a detachment about the W. and S. coasts of the Yokoyama lava area.

TABLE XII. Comparison of Surface Water Temperatures in different parts of the sea around Sakura-jima.

(I.) From Kagoshima Harbour to Krokami and Seto off the N. Coast of Sakura-jima.

Date.	Sea Area of No Temperature Variation, stretching from Kagoshima Harbour to	Temperature Increase at Moe-jima, Ōmoe-zaki, or Krokami.	Temperature Increase near Seto.
Jan. 23rd, 1914.	... ...	2°.3 C	32°.0 C {Seto Strait still unclosed.
April 11th, ,,	Komen and Uranomae.	1°.1—3°.0	8°.1 {In the new Ushine Bay.
Oct. 2nd, ,,	Moe-jima, Ōmoe-zaki, Krokami.	—	—
May 4th, 1915.	Komen, Ōmoe-zaki, Krokami.	—	10°.5 (*Do.*)
,, 5th, ,,	Komen, Ōmoe-zaki, Nagasaki-hana.	—	25°.1 {Close to new lava islets.

(II.) From Kagoshima Harbour to Furusato and Seto off the S. Coast of Sakura-jima.

Date.	Sea Area of approximately No Temperature Variation, stretching from Kagoshima Harbour to	Temperature Increase at		
		Nojiri; Moe-zaki.	Kwannon-zaki; Furusato.	Coast of Ōsumi (Sakkabira).
Jan. 24th, 1914.	... ...	About 12° C.	—	—
April 9th, ,,	Oko-jima.	0°.8 – 1°.4	1°.3—2°.0 C	—
,, 12th, ,,	... ...	{1°.5 {0°.3 – 1°.0	2°.5—3°.8	14°.5 – 18°.0 C.
,, 15th, ,,	... ...	—	1°.9 – 3°.2	19°.3
,, 17th, ,,	... ...	1°.1 – 2.°1	—	—
April 25th, 1915.	... ...	—	1°.0 – 2°.0 apprx.	2°.0 apprx
,, 29th, ,,	Furusato.	0°.0	0°.0	—

50. Surface sea-water temperature along the border of the western lava field. (Table XIII.) Any marked heating effect of the western lava field, whose progressive movement was practically brought to end in the course of a few weeks after the commencement of the eruption, and which had no extensive submergence on account of the shallowness of the strait water, seems to have been limited to the immediate neighbourhood of the lava coast. Thus, according to the observations made in April 1914 to May 1915, the water temperature at the N.W. corner of Hakamagoshi, 600 m distant from the N. lava coast, was always almost exactly equal to that at the middle of Kagoshima Strait. Again, on April 15th, 1914, the temperature at a distance of 500 m from the W. coast of the lava field was 20°.4, indicating an increase of nearly 4° over that of the mid-strait water. As the temperature close to the same coast on the 17th of that month was 25°.0, or nearly 9° higher than at the centre of the strait, we may suppose the heating effect, even in the narrowest part of the latter, to have been reduced probably at a distance of less than 1 km from the lava coast already to a degree equal to that in the Kagoshima harbour.

The highest water temperature of 40° C was observed on April 9th, 1914, over the submerged lava boundary at the S.W. end; this being about 23°.3 higher than at the middle of the strait. The temperature was also high, with the maximum indication of 35°.7, on the 15th of the same month in the Karasu-jima bay on the S.W. coast of the lava field, amounting to an increase of 19°.0 over that of the outside sea water. According to the measurement on April 29th, 1915, the extra heating effect in the same portion of the sea was completely cancelled, while the highest temperature in a long narrow inlet of length = 550 ft., and of mouth opening = 60 ft., at the bottom of the bay in question, was only 25°.3, or 8°.3 higher than in the strait. These comparisons indicate that, in the course of the 1 year between April 1914 and April 1915, the temperature of water at the S.W. or warmest portion of the lava coast was reduced by the amount of about 11° to 15° C. Along the W. lava coast, the temperature decrease during the same time interval was approximately 9° C.

Table XIII. Comparison of Surface Sea-water Temperature in Kagoshima Strait with that along the Coast of the Western Lava Field.

Date.	Middle of Kagoshima Strait.	Beach at N.W. Corner of Hakamagoshi.	Along the Border of the Lava Field.
April 8th, 1914.	16°.7* C	16°.5 C	—
„ 9th, „	16.7*	—	Close to the S.W. end ‡: 17°.5 ; 17°.0 ; 26°.0 ; 35°.2 ; 35°.0 ; 38°.0 ; 40°.0 C.
„ 15th, „	16.7	—	500 m from the W. coast: 20°.4 ; 20°.0. Along the chord of the bay at S.W. coast: 24°.5 ; 26°.0 ; 27°.0 ; 30°.5 ; 35°.7.
„ 17th, „	16.4	—	Close to the W. coast ‡: 20°.0 ; 25°.0.
Sept. 23rd, „	26.1*	26.0	—
April 29th, 1915.	17.0*	—	In the long narrow islet near the site of the former Karasu-jima: 18°.7 ; 20°.3 ; 21°.8 ; 23°.5 ; 24°.5 ; 24°.8 ; 25°.0 ; 25°.3.
„ 30th, „	16.9*	16.7*	Close to the W. coast ‡: 16°.3 ; 16°.4 ; 16°.5.
May 6th, „	17.6*	17.5	—

(*)......Mean deduced from two or more measurements.
(‡)......Over the submerged lava boundary.

51. Temperature of hot spring, etc. For the sake of comparison I give next the results of the temperature measurements made of the hot springs or warm beach rivulets at Furusato and Yunohama (Yubama).

(A) Observations at Furusato.

(i.) *Hot spring of Furusato.* This is located at the beach and is in communication with the sea water in some way, so that the rise and fall of its level is governed by those of the tide. It had previous to the recent eruption a temperature of about 44° to 46°C. According to the measurements made after the commencement of the eruption the hot-spring temperature was as follows :—

Jan. 20th, 1914.	44° C
„ 24th, „	43° C (Air temp.=13° C).

(ii.) *Hot-water well.* The well is situated close above the last-mentioned hot spring, and the water, which has a salty and carbonic-acid taste, is about 3 metres in depth, and rises and falls in relation to the tide. The hot-water temperature, after the eruption, was as follows :—

	Well Tempr.	Air Tempr.	Sea-Water Tempr.
April 21st, 1915 ; 10½ a.m.	46°.6 C	18°.5 C	20°.5 C
„ 27th, „ ; —	45°.3	18°.0 15°.3	21°.2
„ 28th, „ ; 8.20 a.m.	45°.8	21°.7	

(B) Observations at Yunohama (Yubama, or Moto-Arimra).

(iii.) *Beach rivulets.* At Yunohama warm waters with a highly carbonic acid taste were bubbling up from many points in the sandy beach, sometimes resulting in a shallow streamlet 1 foot or so in width. The temperature was as follows :—

Sept. 27th, 1914.	45°.5 C
April 21st, 1915.	37°.5 43°.0
„ 27th, „ (1½ p.m.)	39°.7

(iv.) *Hot-water well.* The warm water in a well near the beach, 4 metres deep, had the temperature of 35° to 36° C :—

April 21st, 1915.	35°.3 C (Air temp.=19°.0 C).
„ 27th, „	35°.0 („ 22°.5).

(v.) *Water issuing from under lavas.* At the time of the author's visit to Sakura-jima in Sept. 1914, there was along the beach a small rivulet issuing from two caves or tunnels, 1 metre in diameter, at the foot of a transverse branch of the lava stream, whose water was hot and had a salty and carbonic acid taste. The temperature was :—

Sept. 27th, 1914. ... ... 60°.8 ; 62°.0 C.

At the time of my visit in April 1915, the rivulet in question did no longer exist, having been buried under the advancing "2nd stage" lava streams.

From the above it seems that the hot spring at Furusato, whose temperature was not much different from 45° C both before and after the eruption, was not affected by the latter at all. It may be that the new production of, or a change in, hot springs and fumaroles, which often, if not always, precedes or accompanies a strong volcanic outburst, is sometimes quite localized and limited to the immediate neighbourhood of the zone of craterlets or their extensions; the village of Furusato being situated comparatively far out of the centres of the recent volcanic disturbances. The temperature of the Furusato hot spring was the same as that of the well close by ; the warm waters in the beach of Yunohama (Yubama) also having a nearly equal temperature.

TABLE XIV. Surface Water Temperature measured in different parts of the Sea around Sakura-jima.

Jan. 16th, 1914, to May 16th, 1915.

Time.	Sea-water Temperature.	Locality.
	January 16th, 1914.	
2.00 p.m.	18.0° C	At the quay, Kagoshima.
3.30	35.0	Near the North entrance of Seto Strait.

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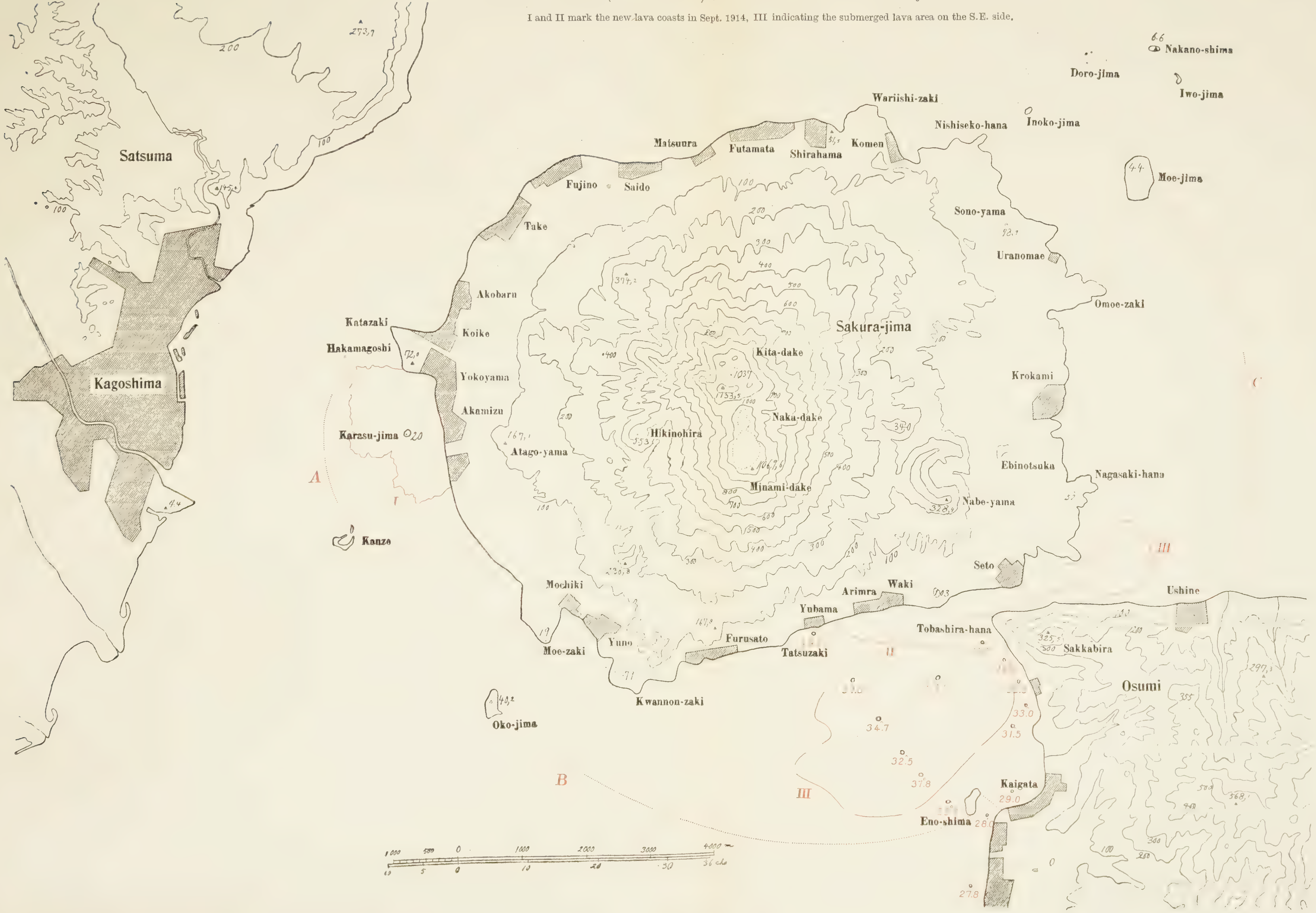
Fig. 118. Map of Sakura-jima showing the Sea Area, the Temperature of whose Surface Water was affected by the Eruption of 1914.

PL. XLVIII.

The red curves A, B, and C mark the approximate boundary of the sea-surface whose temperature was, in Jan.–April, 1914, higher than in the preceding ordinary years. The red figures indicate in centigrade the surface-water temperature on Sept. 20th, 1914, at different points between Eno-shima (near Tarumizu) and the S.E. lava coast of Sakura-jima.

I and II mark the new lava coasts in Sept. 1914, III indicating the submerged lava area on the S.E. side.



Time.	Sea-water Temperature.	Locality.
	Jan. 18th, 1914	
10 a.m.	16°.7 C 16.6 (air : 17°.5)	Coast of Take.
	Jan. 23rd, 1914.	
11.30 a.m.	17°.2	Coast of Fujino.
	19.5	Between Moe-jima and Ōmoe-zaki.
	19.5	In Krokami Bay.
	26.0	At the N. entrance of Seto Strait.
	32.5	
	49.0	
	46.5	
	45.5	
	Jan. 24th, 1914.	
	29°5	At the coast of Nojiri.
	April 8th, 1914.	
8.15 a.m.	16°.5 (air : 11°.8)	At the quay, Kagoshima.
	17.0	Outside the harbour.
	16.5	In Kagoshima Strait.
8.30	17.0	,,
8.40	16.5 (air : 11°.8)	,,
8.45	16.7	Near the Hakamagoshi coast.
,,	17.0	,, ,,
8.52	16.5 (air : 12°.0)	At Hakamagoshi beach.
6.05 p.m.	16.5 (air : 11°.5)	At a small distance from the Hakamagoshi coast.
6.12.	17.0	Middle of Kagoshima Strait.
	April 9th, 1914.	
8.00 a.m.	16°.4 (air : 13°.5)	At the quay, Kagoshima.
8.30	16.5	Middle of Kagoshima Strait.

Time.	Sea-water Temperature.	Locality.
	April 9th, 1914. (*Cont.*)	
8.50 a.m.	16°.8 C (air: 13°.5 C)	Between Oko-jima and the lava area.
9.00	17.9	At Moe-zaki.
9.10	17.8	At Kwannon-zaki.
9.15	18.0	*Do.*
9.20	18.0 (air: 13°.5)	Further on.
9.40	18.0	In Furusato Bay (20°.5 to 21°.0 at Furusato beach, owing to the existence of the hot spring there.)
4.20 p.m.	18.5	Furusato, near the lava area.
	18.5 (air: 13°.2)	,, , near the beach.
	18.0	At Kwannon-zaki.
	18.0	,, ,,
	17.3	At Moe-zaki.
	17.3	Off the coast of Nojiri.
	17.3 (air: 11°.0)	Off the coast between Nojiri and Akamizu.
	17°.5; 17°.0; 26°.0; 35°.2; 40°.0; 35°.0; 38°.0, etc.	Quite close to the S.W. boundary of the western lava area.
	17.0	A short distance off the western lava coast.
	April 11th, 1914; from Kagoshima to Krokami and Seto, and back.	
7.40 a.m.	16°.5 (air: 12°.5)	In Harbour of Kagoshima.
	17.0	Just outside the harbour.
	16.5	Middle of Kagoshima Strait.
	16.4	Off the coast of Take.
	16.6	,, ,, Fujino.
	16.5	About 500 m off the coast of Saido.
	16.5	,, 200 m ,, ,, Shirahama.
	16.4	At Wariishi-zaki.
	16.6	50 m off the Nishiseko cape.
	16.6	Quite close to the Uranomae cape.
	17.7	In Krokami Bay. (Hereafter, falling tide.

Time.	Sea-water Temperature.	Locality.
April 11th, 1914 ; from Kagoshima to Krokami and Seto. (*Cont.*)		
9.45 a.m.	18°.1 C	At Krokami beach.
3.00 p.m.	18.7	Between Krokami and Nagasaki-hana.
	21.6	In the inlet between the Ushine coast and the new lava promontory to the east of the former Seto strait.
3.30	2.45 (air : 16°.7)	
(Hereafter strong W. winds set in.)		
4.00 p.m.	19°.5	At the inside or W. coast of Moe-jima.
	18.6	Coast of Moe-jima, at the N. end.
	17.6	Between Moe-jima and Nishiseko-hana.
	16.7	Off the coast of Komen.
	16.7	At Wariishi-zaki.
	16.7	Off the coast of Saido.
	16.7	Off the coast of Fujino.
	16.5	Between Take and Iso (Kagoshima).
	16.7	,, Hakamagoshi and Kagoshima.
	16.6	Outside the Kagoshima harbour.
6.00 p.m.	16.7 (air : 12°.2)	In the Kagoshima harbour.
April 12th, 1914 ; from Kagoshima to Furusato, Seto, and Ushine, and back.		
8.30 a.m.	16°.5 (air : 15°.0)	In the harbour of Kagoshima. (Falling tide.)
	16.5	Outside the harbour.
	17.2	Middle of Kagoshima Strait.
	17.5	Between Kanze and the western lava area.
	18.0	At Moe-zaki.
	19.4	500 m from the coast, between Moe-zaki and Kawnnon-zaki.
10.00	19.0	At Kwannon-zaki.
	19.1	*Do.*
	21.0	In the Furusato bay.
10.30	21.7 (air : 10°.7)	At Furusato beach.
	20.0	,, ,,

Time.	Sea-water Temperature.	Locality.
April 12th, 1914 ; from Kagoshima to Furusato, Seto, and Ushine. (*Cont.*)		
	21°.5 C	100 m off the lava coast of Arimra.
	31.5	Further on, close to the coast.
	34.5	At the Ōsumi coast.
4.00 p.m.	21.0	Coast of Ushine : mouth of new Ushine Bay.
	25.5	„ „ : mid-length „
	52.0	„ „ : head „
4.45	31.0 (air : 21°.0)	Sakkabira Bay.
	18.0	Off the coast of Arimra.
	19.5	Yubama, at the end of the E. lava area.
6.30	17.5	Between Kanze and the western lava area.
7.00	16.5	At the entrance of Kagoshima Harbour.
April 15th, 1914.		
9.00 a.m.	16°.7 (air : 14°.5)	Just outside the harbour of Kagoshima.
	16.7	Middle of Kagoshima Strait.
	17.4	Near the coast of the western lava field.
	17.8	„ „ „
	20.4	About 500 m off the western lava coast.
	20.0	„ „
	24°.5 ; 26°.0 ; 27°.0 ; 30°.5 ; 35°.7 ; etc.	At points on the chord, or line joining the two ends of new Karasu-jima Bay.
	18.5	At Kwannon-zaki.
	20.0	At the coast of Furusato.
	18.7	100 m off the coast of Arimra.
Noon.	36.0	In new Ushine Bay.
3.30 p.m.	27.0	50 m off the coast of Arimra.
	18.7 (air : 18°.0)	At Kwannon-zaki.
April 17th, 1914.		
8.00 a.m.	16°.5 (air : 11°.4)	Kagoshima Harbour, at the quay.
	16.4	Middle of Kagoshima Strait.

Time.	Sea-water Temperature.	Locality.
	April 17th, 1914. (*Cont.*)	
2.30 p.m.	18°.5 C	At Nojiri, sea beach.
	17.5	At the mouth of Nojiri Bay.
	20.0–25°.0	Along the coast of the western lava area, over the submerged portion.
	September 23rd, 1914.	
7.30 a.m.	25°.6 (air : 23°.0)	In Kagoshima Harbour, at the pier. (Falling tide.)
	25.6	Just outside the harbour.
	25.5	Middle of Kagosbima Strait.
	25.8	,,
	25.8 (air : 21°.0)	,,
	25.6	Near Hakamagoshi.
	26.0	At Hakamagoshi beach.
5.00 p.m.	26.5	Middle of Kagoshima Strait. (Rising tide.)
	26.5 (air : 22°.0)	,,
	26.4	,,
	26.5	Near the Kagoshima coast.
	26.3	In Kagoshima Harbour.
	September 25th, 1914 ; from Tarumizu to Seto, and back.	
Noon.	27°.8 (air : 28°.6)	At Tarumizu ; beach, of 1 foot water depth. (Falling tide.)
	27.5	,, ; at 35 m from beach.
	27.3	,, ; at 100 m ,,
	27.5	200 m off the coast of Shiroyama-hana.
0.30 p.m.	27.8	At Ara-zaki. (The course of the boat was hereafter directed straight to the W. end of the Arimra lava field).
	29.7	500 m off the west side of Eno-shima.
1.05	31.8	Just past Eno-shima.
1.12	32.5	Midway between Eno-shima and the new Arimra lave coast.
1.21	34.7	About 400 m off the projecting lava coast of Arimra.
1.23½	40.7	A little further on.
1.23½	30.0	Still a little further on.

Time.	Sea-water Temperature.	Locality.
September 25th, 1914 ; from Tarumizu to Seto, and back. (*Cont.*)		
1.31½ p.m.	57°.0 C	About 70 m from the lava coast of Yunohama.
	44.0	Further on.
	49.5	In the Yunohama bay.
(The course was hereafter directed east towards the Sakkabira bay.)		
	57.5	Over the submerged lava outflow, where gases were bubbling up.
	52.0	100 m off the lava coast.
1.58	37.5	200 " "
2.03	44.5	At the mouth of an inlet.
2.17	35.5	In the Sakkabira bay: 500 m from the Ōsumi coast and 300 m from the lava boundary.
2.21	34.2	At the Sakkabira anchorage (coast of Ōsumi), about 500 m from the lava.)
(The course directed from Sakkabira straight to Tarumizu.)		
3.35	33°.5	Quite close to the coast. (Falling tide.)
	33.0	Along the coast, 100 m further southward.
4.01	31.5	Off the cape of Hijiri-zaki.
4.15	29.0	Between the Eno-shima and Kaigata.
	28.0	At the S. entrance of the Eno-shima channel.
4.52	27.9	Close to Ara-zaki.
5.15	27.2 (air : 24°.7)	At Tarumizu, beach.
September 26th, 1914.		
2.00 p.m.	28°.5 (air : 26°.5)	At Ushine, 9 metres from the beach.
September 27th, 1914 ; from Tarumizu straight to Yunohama, and back.		
7.45 a.m.	26°.7 (air : 21°.5)	At Tarumizu, 300 m from the shore. (Falling tide.)
7.50	26.3	
8.00	27.1	Near the Ara-zaki.
8.09	27.7	Past the Ara-zaki.
8.20	27.8	Approaching Eno-shima, on the west side.
8.27	28.3	Outside the islet of Eno-shima.

Time.	Sea-water Temperature.	Locality.
September 27th, 1914; from Tarumizu to Yunohama, and back. *(Cont.)*		
8.40 a.m.	32°.5 C	Beyond Eno-shima.
8.44	33.7	A little further on.
8.50	29.7	About 800 m from the Arimra lava coast.
9.01	30.1	In the Yubama bay.
4.00 p.m.	60.0	,, ,, ,, , where the water was steaming.
4.48	28.5	Off the west side of Eno-shima.
5.04	28.7	Just beyond Eno-shima.
5.38	27.7 (air : 21°.6)	At Ara-zaki.
6.00	27.4 (air : 21°.7)	At Tarumizu.
October 1st, 1914.		
8.40 a.m.	24°.5 (air : 18°.8)	In Kagoshima Harbour.
	25.0	Just outside the harbour.
8.50	25.0	Between the Iso coast and Hakamagoshi.
9.00	25.0	,, ,, ,, ,,
9.20	24.5	300 m off the coast of Take.
October 2nd, 1914; from Komen to Krokami, and back.		
7.14 a.m.	24°.5 (air : 19°.5)	In Komen Bay.
7.21	24.7	Off the coast of Komen.
7.32	24.1	Further on.
8.45	25.0	In Krokami Bay.
1.53 p.m.	25.5 (air : 24°.5)	,, ,, (Rising tide.)
2.15	25.5	At Omoe-zaki.
4.40	25.5 (air : 23°.7)	Between Komen and Moe-jima.
5.05	25.2	At the entrance of Komen Bay.
October 3rd, 1914.		
10.40 a.m.	25°.0 (air : 23°.0)	Akobaru, at beach.
10.56	24.9	Middle of Kagoshima Strait.
11.04	24.9	,,

Time.	Sea-water Temperature.	Locality.
October 3rd, 1914. *(Cont.)*		
11.14 a.m.	24°.8 C	Outside the Kagoshima harbour.
11.19	24.7	In the Kagoshima harbour.
April 25th, 1915 ; from Furusato to Seto and Ushine, and back.		
8.00 a.m.	19°.0 (air : 16°.5)	At coast, between Furusato and Yubama.
8.05	18.0 (air : 11°.5)	At the entrance of Yubama bay.
	18.0	Close to the S.W. corner of the lava area.
	18.5	Further on, about 100 m from the lava coast.
	30°.0 ; 28°.0	In a small inlet.
	41°.0 ; 38°.5 (air : 16°.8)	In a small triangular pond, (width=100 m, length=200 m) at the bottom of the above mentioned inlet.
	39°.0	In a bay (diameter=300 m).
10.20	20°.0 ; 21°.5	30 m off the lava coast of Arimra.
Noon.	19.0	At the coast of Ōsumi, ½ km south of the former Seto strait.
3.00 p.m.	20°.8 (air : 20°.0)	Coast of Ushine (Fumoto), not far from the mouth of the inlet formed between the latter and the lava promontory.
6.15	40°.0	About 50 m off the extreme point of the maximum protuberance of the Arimra "2nd stage" lava outflow.
April 29th, 1915 ; from Furusato to Kagoshima Harbour.		
7.25 a.m.	17°.5 (air : 20°.5)	Off the coast of Furusato.
7.40	17.5	At Kwannon-zaki.
8.55	17.5 (air : 18°.5)	Off the west coast of Oko-jima.
9.30	17.5	Between Oko-jima and Nojiri.
11.40	17.2	Off Akamizu, near the S.W. projecting corner of the lava area.
11.50	17.6	At the last mentioned projecting corner.
Noon.	18.7 (1) 20.3 (2) 21.8 (3) 23.5 (4)	In a long narrow inlet (width=60 ft., length=550 ft.) near the place where Karasu-jima formerly existed : from the mouth (1) successively to the head (8) of the small bay.

Time.	Sea-water Temperature.	Locality.
April 29th, 1915 ; from Furusato to Kagoshima Harbour. (*Cont.*)		
Noon.	24°.5 C (5) 24.8 (6) 25.0 (7) 25.3 (8) ……….. (air : 22°.5)	(See the above remark.)
0.10 p.m.	16.5	Again at the mouth of the new Karasu-jima bay.
0.20	17.6	Middle of Kagoshima Strait.
0.40	17.0	,,
May 4th, 1915 ; from Komen to the New Lava Islets, and back.		
6.30 a.m.	17°.4 (air : 13°.0)	Komen, beach. (Rising tide.)
6.40	17.0	In Komen Bay.
7.00	17.2	Beyond Nishiseko-hana.
7.05	17.0	Off the coast of Moto-Komen.
7.55	17.0	At Moto-Komen anchorage.
8.07	17.2	At the Uranomae cape.
8.25	17.2	At Ōmoe-zaki.
8.40	17.5	In Krokami Bay.
1.50 p.m.	19.7 (air : 21°.8)	Between Krokami and Nagasaki-hana. (Hereafter, falling tide.)
2.10	19.0	Off Nagasaki-hana.
2.20	22.7	Among the new lava islets.
2.30	23.0	,, ,, ,,
4.15	18.2 (air : 18°.5)	Outside the area of the new lava islets.
4.50	18.0 (air : 18°.0)	Off Omoe-zaki.
5.05	17.5 17.7	Off the Uranomae cape.
5.35	17.9 (air : 14°.0)	Off Hirabana.
5.40	17.7	Off Nishiseko-hana.
April 30th, 1915 ; from Kagoshima Harbour to Hakamagoshi, and back.		
8.00 a.m.	16°.4 (air : 18°.5)	In Kagoshima Harbour.
8.10	16.6 (air : 14°.3)	Outside the harbour.

Time.	Sea-water Temperature.	Locality.
April 30th, 1915 ; from Kagoshima to Hakamagoshi and back. (*Cont.*)		
8.40 a.m.	16.6° C	Middle of Kagoshima Strait.
9.00	16.5	Near Hakamagoshi.
9.05	16.3	*Do.*, in still water.
9.10	16.4	Over the submerged lava area, in a small bay
9.20	16.5	Near Hakamagoshi, over the submerged lava area.
9.30	16.5	At Hakamagoshi, beach.
5.15 p.m.	16.9	,, ,,
5.35	17.6	Mid-Strait, in rising tide current.
5.40	16.8	Outside the rising tide current.
,,	16.9	,, ,,
5.45	16.8	Middle of Kagoshima Strait.
6.00	16.5	Outside the harbour.
6.15	18.0 (air : 14.0°)	In the Kagoshima harbour.
,,	17.8	,, ,,
May 5th, 1915 ; from Komen to the New Ushine Lava Islets Group, thence to Kagoshima Harbour.		
6.00 a.m.	16.9° (air : 14.5°)	Off the coast of Komen.
8.10	22.0 (air : 25.0°)	Among the new lava islets off Ushine.
9.45	43.5 (air : 18.8°)	Alongside a new islet at the extremity of the lava stream.
10.15	18.5 (air : 19.0°)	Off Nagasaki-hana.
11.05	18.5 (air : 19.5°)	Close to Ōmoe-zaki.
11.20	18.5	Off the coast of Uranomae.
11.40	19.2 (air : 20.4°)	Off Nishiseko-hana.
0.25 p.m.	18.3 (air : 21.4°)	Off the coast of Shirahama.
0.50	18.8	,, Saido.
1.15	18.8 (air : 16.8°)	Off the coast, between Fujino and Take.
1.50	18.5 (air : 17.5°)	In the Kagoshima strait, off the coast of Iso.
2.15	18.2	Outside the Kagoshima harbour
2.18	17.7 (air : 18.0°)	In Harbour.

Time.	Sea-water Temperature.	Locality.
May 6th, 1915 ; from Kagoshima Harbour to Hakamagoshi, and back.		
7.20 a.m.	16°.5 C (air : 18°.5)	In Harbour of Kagoshima. (Rising tide.)
7.30	16.5 (air : 15°.0)	Just within the harbour entrance.
7.35	16.7	Outside the harbour.
7.45	17.2	Middle of Kagoshima Strait.
8.00	17.2 (air : 16°.0)	,, ,,
8.25	17.2 (air : 16°.0)	In Kagoshima Strait, about 600 m from the lava coast.
9.15	17.5 (air : 18°.0)	Hakamagoshi beach.
4.30 p.m.	18.6 (air : 16°.8)	Mid-Strait. (Hereafter falling tide.)
4.48	18.5	Outside the harbour.
4.55	18.2	In Harbour.

Chapter VIII. Second Stage Lava Outflow.

52. 2nd stage lava flow and its median furrow. (See fig. 119, and also the map on Pl. IX. in the preceding Number of the Bulletin.) The lava streams which began to issue from the different eastern craterlets soon after the commencement of the eruption may be regarded as composing the 1*st stage outflow*, and continued to move downwards or outwards with rapidly decreasing rate for about 12 months till the end of 1914. The outflow buried during this time interval the villages of Seto, Arimra, and Waki, and the whole S.E. portion of the island, the southern boundary of the area above water projecting about 850 metres beyond the former sea coast. At the end of March and the beginning of April in 1915, namely $1\frac{1}{4}$ years after the commencement of the eruption in January 1914, there took place what may be termed the 2*nd stage outflow* of lava, which has been carried on quietly and, not directly from the craterlets themselves, but from a few orifices or crevices at the southern coast of the south-eastern lava field. The new lava outflows, which were very black, in contradiction to the ash-covered and more or less weathered 1st stage lavas, expanded each from a point source into the form somewhat like that of a chrysanthemum leaf, the greatest elongation amounting to nearly 900 m. According to the Chief Engineer Ōi, of the Kagoshima Prefecture, who inspected on April 6th, 1915, the lava field in question, the strong and almost detonative steam emission was then taking place from different points of the periphery of the latter, whose progressive displacement could be plainly observed, and which was seen during the night to send up a number of fiery columns.

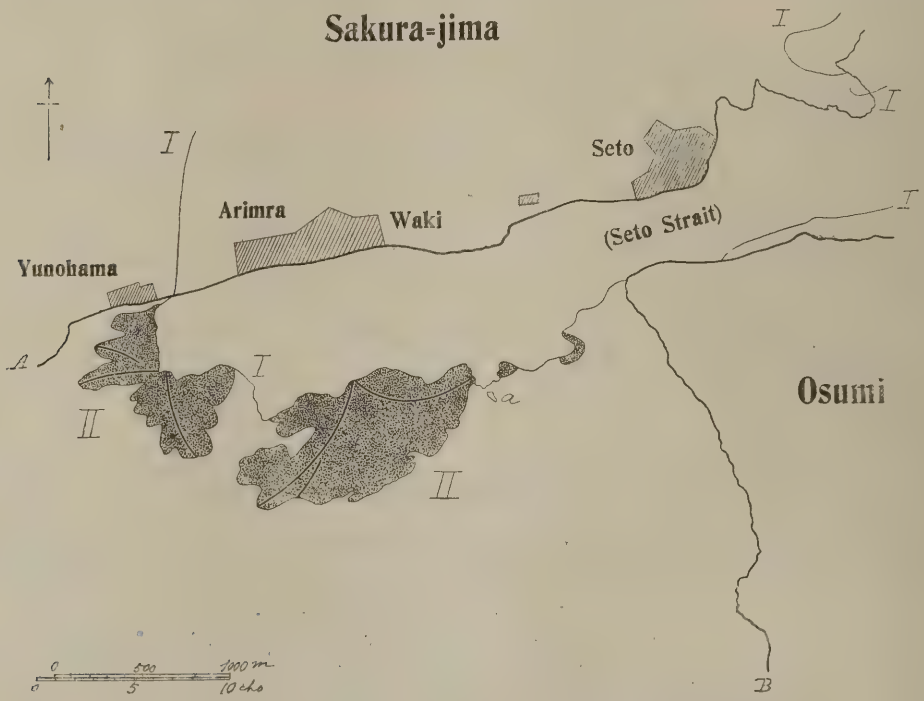
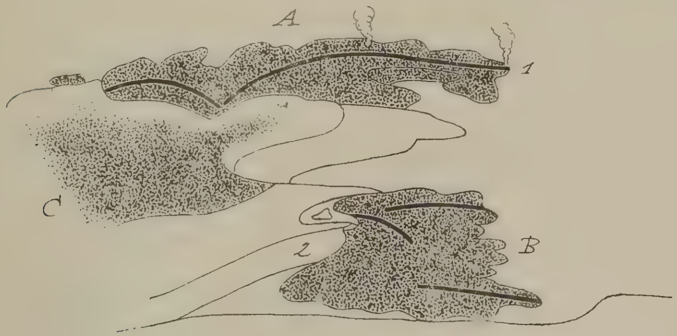


Fig. 119. Map showing the Area of the 2nd Stage Lava Outflow.
I......Boundary of the lava area above the sea, in Dec. 1914. II......2nd stage lava outflow.
a......Arimra-jima, a new lava islet.

A special feature of the 2nd stage outflow is the existence of a sort of *median furrow*, or a narrow groove extending along the entire middle axis of each lava protuberance. These lines, a dozen metres or more in width, could distinctly be observed with naked eye from the top of the Minami-dake, or a distance of over 4 km. (See figs. 120 and 126.) To explain their formation, let *a c b* (fig. 121) be

Fig. 120. View from the Top of Minami-dake of the 2nd Stage Lava Outflow.



The dark portions indicate the black lavas, either (A and B) forming the 2nd stage outflows, pushed out from the side, or (C) occupying the hollow surface space of the earlier lava field.
(1)......Temporary geyser. (2)......Side moraine at Yunohama.

Diagrams showing the formation of the Median Furrow.

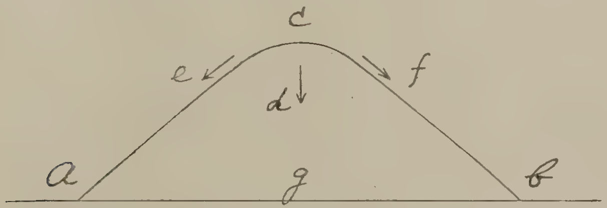


Fig. 121. Section of a lava stream, in the initial condition.

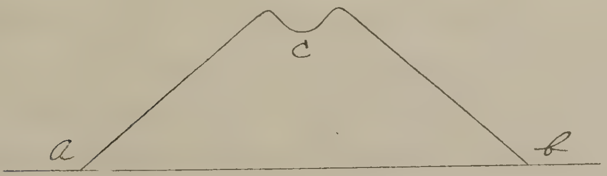


Fig. 122. Section of a lava stream, in the modified condition.

the cross section of a lava stream, the height *cg* varying from several dozen metres to over 100 m. The inside of the lava stream retains for a long time its red-hot molten condition and flows on more rapidly than the quickly solidifying surface *a c b*, causing the top portion *c* to be depressed through some distance till *d*. At the same time the lava at the ridge tends to run down the two sloping sides, as indicated by the arrows *e* and *f*. Consequently the lava stream will get a groove along its longitudinal axis, like the midrib of a plant leaf, whose two opposite sides are turned outwards. It will be noticed that the *median furrow* presents some points of similarity to the *cleavage canal* described in § 41. If the 2nd stage outflow had taken place on an inclined plane, the lava area would have been more nearly symmetrical as, for instance, is sketched in figs. 123 and 124. In the present case, however, the main prolongation took place in the direction of the deeper water, rendering the form one-sided.

Diagrams (plans) illustrating the spreading out of the new lava area.

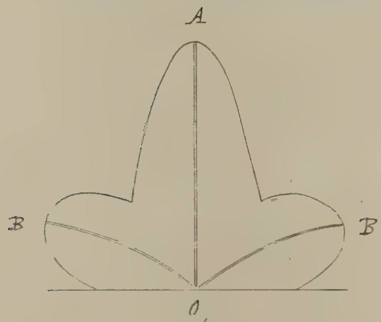


Fig. 123.

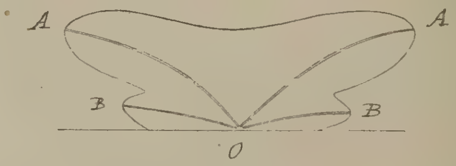


Fig. 124.

Fig. 123. Case of a single principal frontal outflow (OA), followed by two side flows (OB).
Fig. 124. Case of two principal bifurcating outflows (OA), followed by two side flows (OB).
O... Orifice.

It is hereby to be noticed that, on the south-eastern lava area, the black issues of later date filled up different points *within* the 1st stage field, sometimes occupying a hollow space of considerable extension within the side "moraines." In these instances, however, there was no evident indication of the median furrow.

Seto "strait" lava. The Seto "strait" lava and its eastern extension show no system of well developed median furrows, the whole field forming a lengthy projection with a series of parallel longitudinal dislocation planes. At its eastern promontory end, however, there was exposed to view the cross section of a sort of a median furrow about 6 m in width and 5 m in height, as indicated in fig. 125.

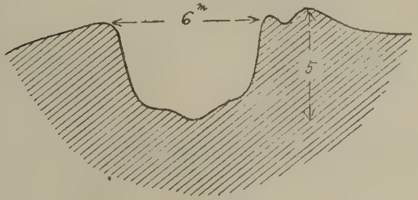


Fig. 125. Approximate section of an imperfect median furrow at the Ushine end of the Seto "strait" lava.

Western lava field. The lava mass from the western craterlets was much smaller in amount than that from the eastern ones, and flowed down into the shallow Kagoshima channel. On the western field there was no appearance of the general *2nd stage* outflow, principally on account of the comparatively small thickness of the lava mass, and of the short time interval during which the western craterlets were active. I have observed, however, at the north-western extremity of the lava area, a case of small secondary or transverse lava stream, probably formed sometime later than the main course itself, showing at the end, in the form of a cross section, a more or less well-defined median furrow whose bottom was about 2 m in width. Another case of small transverse lava stream was found at the north boundary slope of the lava field above Akobaru; the flow, which bifurcated at a distance below the outlet, having been formed at the commencement of 1915 or the end of 1914, as it had no existence at the time of my visit in October of the latter year.

The local outflow of black magma, which took place at many points of the western lava area, was in this case due mainly, not to the continued issue from the craterlets themselves, but to the squeezing out of the internal fluid portion in consequence of the subsidence of the hardened surface layer of the main lava streams.

53. Note on old lava promontories of Sakura-jima. The beautiful form of the *2nd stage* lava area is due to the quiet and steady outflow of magma from the inside of the 1st stage lava streams, whose thickness is considerable. We may reasonably suppose that a similar process took place also in the cases of former great eruptions of Sakura-jima ; the map indicating a number of the lava promontories of the form sketched in fig. 123. The Ōmoe-zaki, Nishiseko-hana, and Wariishi-zaki on the N.E. side, and the Moe-zaki and Kwannon-zaki on the S.W. side, of the island are probably due not directly to eruptions, but were each formed by a 2nd stage lava outflow several months or a couple of years after the initial strong outbursts.

54. Relation between cleavage canal and median furrow. In § 38, it has been concluded that the massive islets off the coast of Ushine moved together with, that is to say, stood on the submerged prolongation of, the lave promontory, at whose apex they had been formed. Consequently, the molten material, which formed the islets with cleavage canal must have been pushed up through orifices in the upper surface of the submerged lava stream. If, on the other hand, the lava be squeezed out freely and in a sufficient quantity, sidewise or horizontally from the solid vertical front or flank of the lava stream, there would be formed the median furrow discussed in § 52. The *cleavage canal* and the median furrow are thus to be regarded as representing the two varieties of the result of a particular process of lava outflow.

55. Geyser phenomena. At the time of my 4th visit to

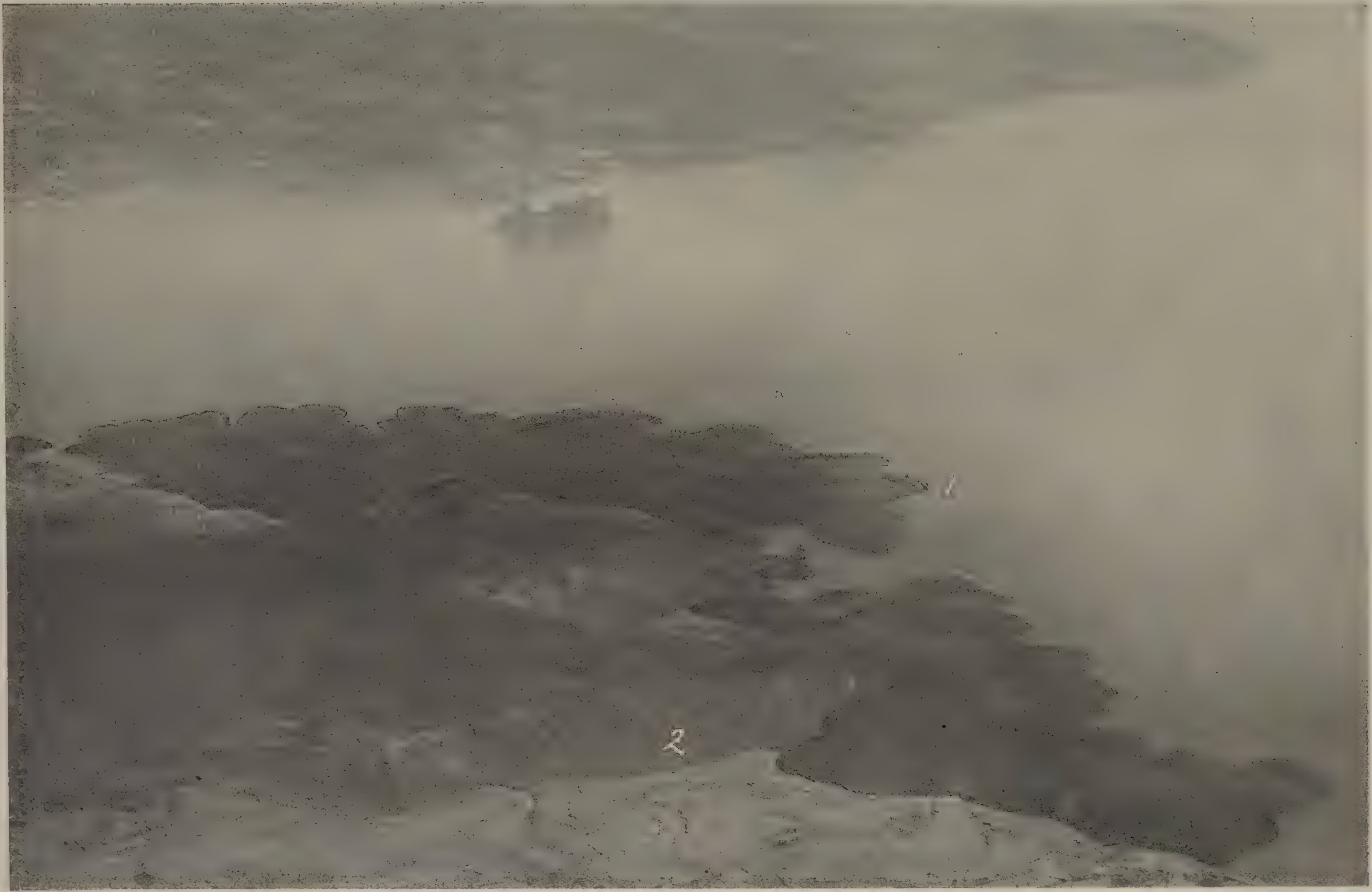


Fig. 126. View taken from the top of Minami-dake of the 2nd Stage Lava Outflow, showing the Median Furrows.

(1), Shiwofuki-zaki. (2), Side " moraine " at Yunohama. (3), Eno-shima.

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Sakura-jima Eruption of 1914. (F. Omori, photo.)

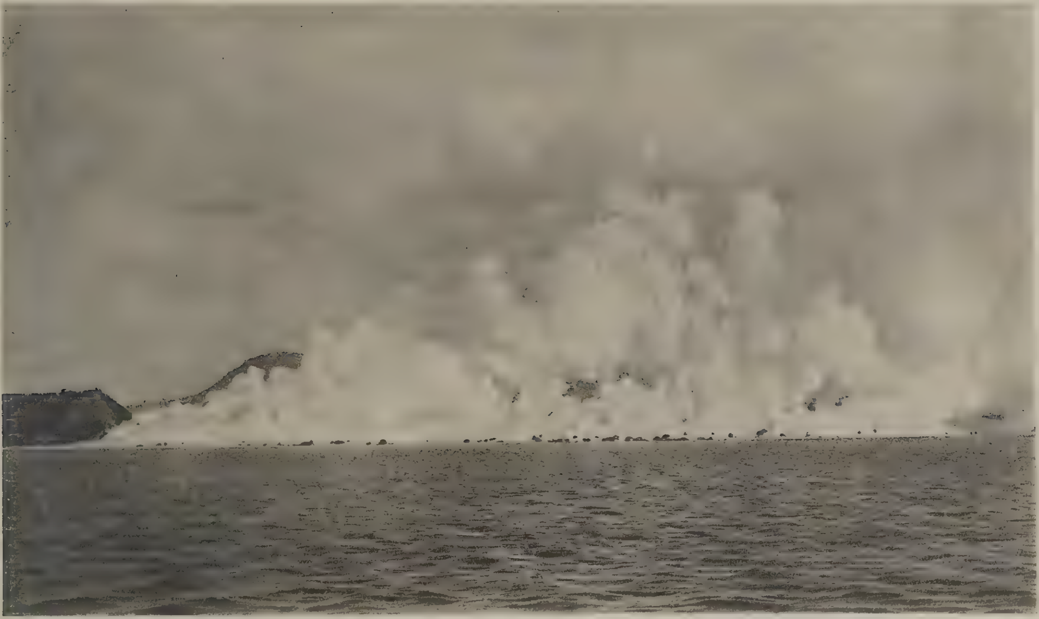

Fig. 127. Vigorous evaporation of sea-water from the lava area to the S. of Hakamagoshi (shown at the left-hand side of the figure.) (Jan. 19th, 1914.)

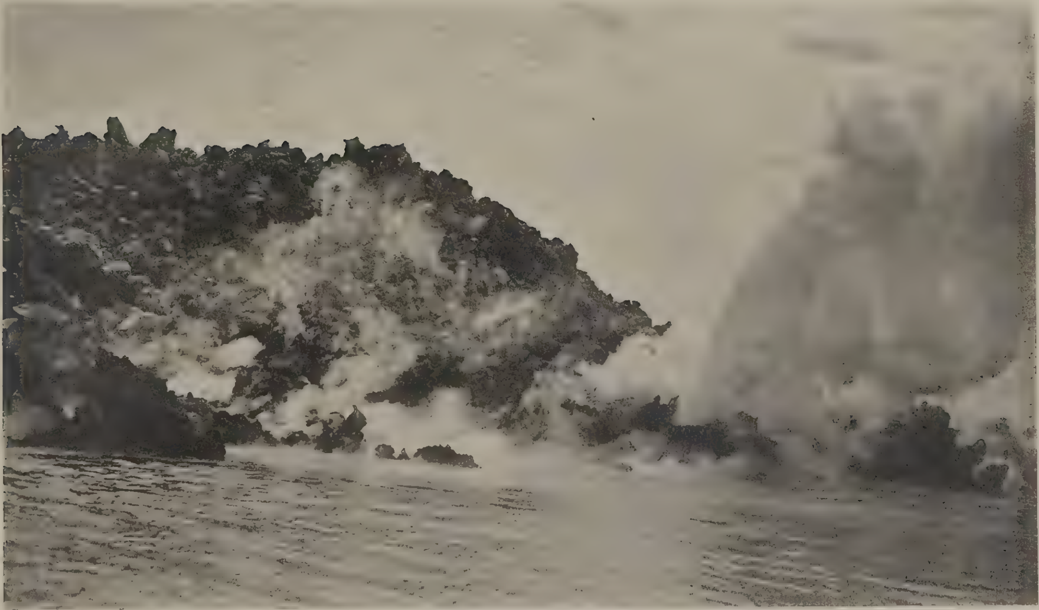

Fig. 128. Geyser produced at Shiwofuki-zaki. (April, 1815.)

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Sakura-jima in April and May, 1915, small quantities of steam were feebly rising from numerous points in the eastern lava field. Amongst the others, the issue of pure white steam from the ends of the new lava protuberance extending furthest into the sea, and of the next one on the west side, of nearly equal elongation, which we have named Arimra-zaki and Shiwofuki-zaki ("water-spouting cape") respectively, were quite characteristic and frequently accompanied by loud rushing sounds like the volcanic noises emanating from the crater of Asama-yama when vigorously emitting gases and steam, or like the puffs of a locomotive when ascending a sloping ground. These lasted each time for several minutes. Thus, in one of the steam ejections from the Shiwofuki-zaki, on April 25th, 1915, the sound was heard for five min. between 7.05 and 7.10 a.m. at Furusato 2.0 km distant from the source of disturbance, the white vapours projected up streaming down in the fashion of ash-smokes. Again, on April 27th, the sounds from the same source were heard at Furusato with a moderate loudness for five min. from 2.19 to 2.24 p.m., continued more or less distinctly for further 4 min.; also moderately loud for about three min. between 4.42.30 and 4.45.20 p.m., continuing faint for three min. more. In these cases the frequency of the puffing noises was about 3 in one second. The Shiwofuki-zaki was also active on the afternoon of the 28th of April (1915): the rushing sounds, which accompanied the steam emission, commenced from 5.09.00 p.m., were loud for 6⅓ min. till 5.15.20 p.m., remained faint till 5.19.40 p.m., then continued with an increased intensity till after 5.30.00 p.m., and ceased to be audible at 6.05.00 p.m.; the vapours, however, continuing to rise more or less for many minutes more.

The Arimra-zaki, of the greatest elongation, was naturally the main or most energetic branch of the lava outflows, and at the end of April 1915 must have been still continuing its progressive movement, though with a small rate (§ 56). When approached in a boat during the day time, on the 25th of the same month, the apex of the cape was found cracked and the inside red hot molten mass was exposed to view, while the steaming crustal lava blocks constantly crumbled down, hissing into the water. During the clear nights of the 21st and 26th, April, some faint red spots at the same place were visible from Furusato.

While sailing on the morning of April 25th, 1915, in a small boat along the new Arimra lava coast, I had the fortune to witness from a short distance one of the powerful steam and water ejections from the apex of Shiwofuki-zaki which was really the display of a geyser in a small scale. (See fig. 128.) The ejection, accompanied with loud rumbling sounds, began at 9.37 a.m. and lasted $10\frac{1}{2}$ minutes, during which interval the white steam was sent up to the height of 40 or 50 m, while a water spray was thrown from an orifice at sea-level and about $\frac{1}{2}$ metre in

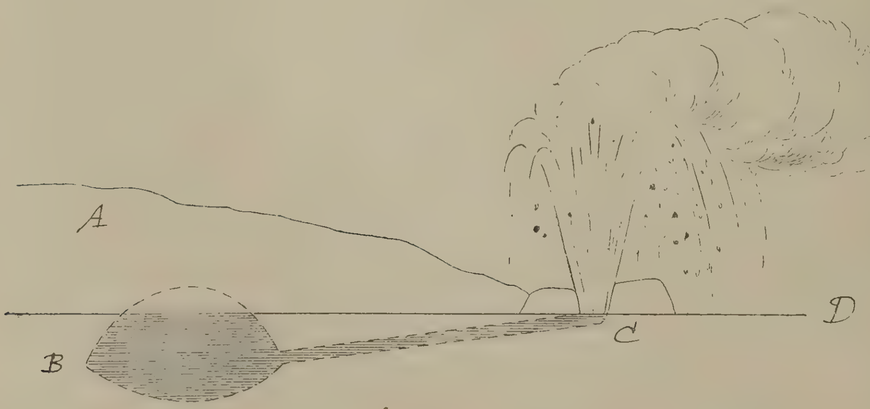

Fig. 129. Diagram illustrating the geyser phenomena at the end of the new lava Shiwofuki-zaki.

D......Sea surface.
B......Interior chamber.
A......Lava stream.
C......The orifice.

diameter, through the vertical distance of about 5 metres so vigorously that small lava fragments were often projected up to a height of a few metres. The process of the geyser formation may be illustrated diagrammatically as in fig. 129; the orifice *C* being supposed to be in communication with a highly heated interior chamber *B*, whose upper portion is above the sea-level. When the vapour tension generated in the chamber *B* was sufficiently increased and reached an amount more than counterbalanced by the water pressure in the column *BC*, there would result a steam and water spouting from the orifice *C*. Now the velocity with which the water was projected from the latter was approximately $\sqrt{2 \times 10 \times 5} =$ 10 m/sec. Hence the total amount of the water ejected during the eruption above described would be about $\pi \times \frac{1}{16} \times 10 \times 630 = 1220$ c.m. or $\overline{10.7\text{m}^3}$. The volume of the chamber *B* here supposed would thus roughly be equivalent to that of a 10-metre cube.

56. Forward progress of lava. The 2nd stage lava outflow seems to have been completed in a comparatively short time interval. Thus, between the 23rd and 28th of April, 1915, there was no special progress of the new lava protuberances, although the furthest end of the latter still indicated red-hot portions. Measuring from a given point on the head of Tatsu-zaki (lava flow of 1779 situated to the W. of Yunohama), the angle between the S. base of Eno-shima and the end of the new Shiwofuki-zaki, which exhibited the geyser phenomena, was increased from $0° 15'$ to $0° 45'$ in the course of 5 months between April 23rd and Sept. 22nd, in 1915. As the distance of the point in question from the place of observation was 1600 m, this angular difference corresponds to a total forward progress of about 14 m of the apex of the lava cape, or to an average rate of approximately 0.1 m per day in the time interval concerned.

Chapter IX. Earth-heat Phenomena at Saido.

57. Earth temperature. The orchard of Nishimoto (西本) behind the village of Saido (西道) at the N.W. coast of Sakura-jima has recently become a scene of a curious earth-heat development, the temperature of the ground having been remarkably raised and much scaring the people in the neighbourhood, who imagined this to be a forerunner of a possible volcanic eruption from the spot affected. The first perceptible symptom of the change was the dying of the peach trees in March, 1915, at the lowest part or N. end of the area, and the same effect gradually spread upwards or southwards ; subsequently the *Quercus acuta*, *Quercus serrata*, *Eriobotrya japonica*, etc. also gradually died. The area in question, which is entirely pumiceous, probably to a depth of several metres, is on a gentle slope at the foot of a hill belonging to the outskirt of Kitadake, at a distance of about 600 m from the coast and at a height of 70–80 m above sea level. The surface accumulation of ejecta

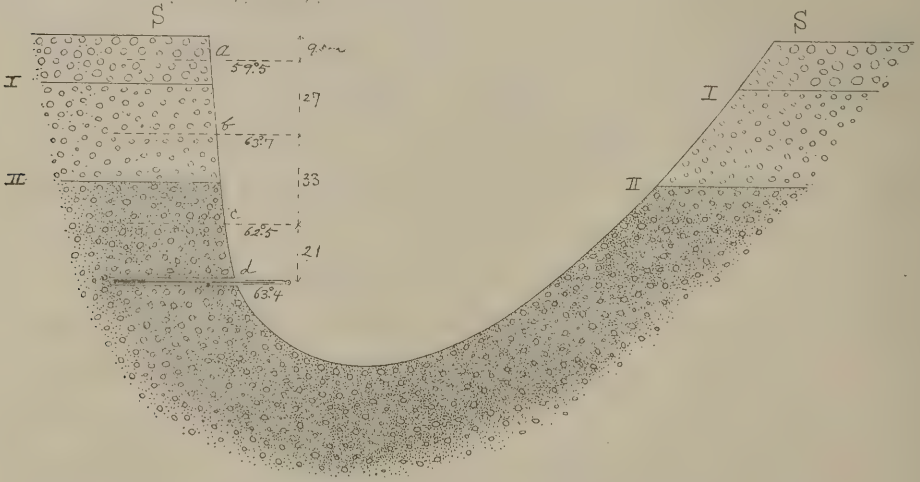

Fig. 130. Sectional diagram illustrating the accumulation of pumice and the measurement of the earth temperature at Saido.
S……Surface. a, b, c, d……Places of temperature measurement.
SII……New pumice accumulation. S I……Coarse pumice. I II……Finer pumice.

due to the recent eruption was 36 cm, of which the upper layer, 9 cm thick, consisted of coarse pieces, and the lower layer, 27 cm thick, of fine pieces of pumice. The underlying portion was made up of fine old pumice pieces of dark colour. (See fig. 130.)

At the time of the present author's visit, on Oct. 1st, 1915, the heat area, marked out by a complete death of the trees and by a very slight issue of vapours from a few points, was nearly a circle, 156 metres in diameter, and, within it as well as in the neighbouring ravines and pathways leading up from the coast, there was perceived strongly a bad smell of gases like that of dilute chlorine mixed with benzine fumes, and exactly similar to what was experienced at the hill side above the village of Take, on the W. side of Sakura-jima, where in the previous spring an ox had been killed and several persons taken ill, probably from the suffocation due to the presence of carbonic acid. At this locality the gases seem to be firmly absorbed in the pumice, as was also the case in the vicinity of Hakamagoshi where the ash and pumice still preserved their bad smell in 1915.

On making with a thermometer the determinations of the earth-temperature at different points it was found out that the hottest portion was a small circle about 20 m in diameter, situated excentrically near the upper boundary of the heat area. (See fig. 131.) The method of the observation was as follows :—the thermometer was inserted in a small hole made with a stick vertically or obliquely at the bottom, or horizontally at the side, of an excavation (fig. 130) ; care was taken to prevent the free ingress of the external air into the hole, by stopping the mouth with small pumice pieces ; this last precaution being necessary to insure the accuracy of the result. During the temperature measurements, from 10 a.m. to 3 p.m. (Oct. 1st), the weather was calm and fair, but sultry, the air temperature being 28° to 29°C. After 3 p.m. there was a precipitation of rain, accompanied by lightnings. The earth-temperatures determined at differents points in the hottest portion, at depths varying from a few cm up to about 1 metre, were as follows:—

Earth Temperature measured in the Hottest Area.

Size of Excavation.	Depth where the temperature measurement was made.	Earth Temperature.	Remarks.
Length Breadth Depth 90×60×90 cm.	(Measured near the surface.)	64.6° C	Slightly steaming from bottom. Air temperature=28.0° C.
	"	62.5	
	(Measured at bottom.)	61.5	
150×90×120.	9 cm.	59.5	In the new coarse pumice layer. (Air insulation imperfect.)
	36	63.7	In the layer of new fine pumice
	69	62.5	In the older layer of black fine pumice.
	90	63.4	*Do.*
(Smll excavation.)	45	61.0	In the new pumice layer.
(Small hole; Depth=60 cm.)	20	54.5	The hole was made vertically with a stick.
	15	58.5	Repeated after half an hour.
(Small hole.)	(Oblique depth =9 cm.)	57.5	The hole was made with a stick obliquely at the base of a tree. (Air insulation imperfect.)
30×45×30	15	49.0	(Air insulation imperfect.)

The several excavations utilized in the temperature measurements had been dug several weeks previously. This fact, however, does not affect the accuracy of the result, as the heated gases must have been diffused within the limit of small dimensions almost uniformly through the mass of the pumice layers. To this last mentioned characteristic of the ground is probably to be attributed the approximate constancy of the temperature at varying depths, at least till about 1 m below the surface ; there being, so far as these observations are concerned, no increase of temperature at the bottom of the excavations. It is of course not to be assumed that the temperature remained unchanged to a great depth, say, of over several metres.

The maximum earth temperature in the hottest portion was thus 64°.6 C, while that in the immediate neighbourhood at a distance of 16 m sidewise to the west of the hottest portion was 47°.8 C at 1½ feet depth. At a point 2½ m within the upper (or southern) margin of the heat area, where there was a strong bad smell, the earth-temperature was 45°.0 C ; but at a distance of 2 m outside the same boundary line, where there was no bad smell and where the trees were green, the temperature 2 feet below the surface fell abruptly to 33°.5 C. 25 metres to the N. of the hottest portion,

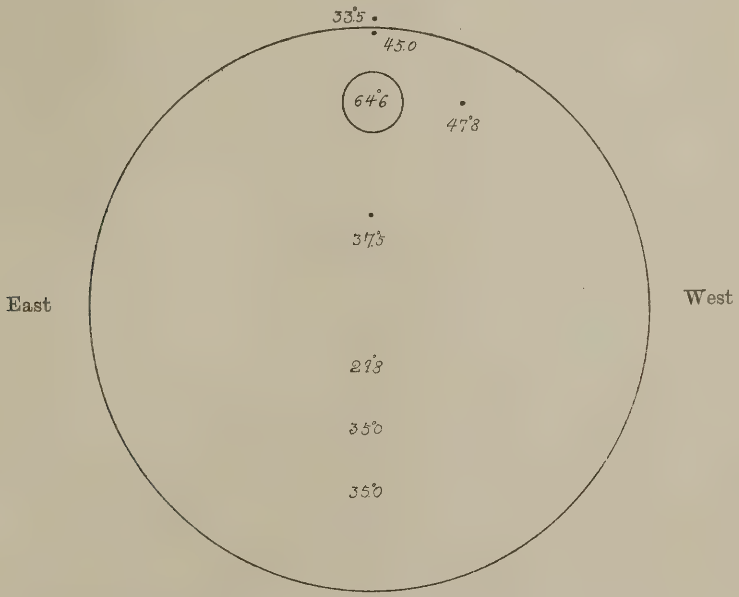

Fig. 131. Plan showing the Variation of the Earth Temperature in the Saido Heat-Area (large circle), on Oct. 1st, 1915. The small circle marks the spot of specially high soil temperature. The upper part of the figure corresponds to the higher slope.

the temperature was 37°.5 C at $1\frac{1}{2}$ feet depth. In the lower and more level part, within the heat area, the temperatures at three different places, measured $\frac{1}{2}$, $2\frac{1}{3}$, and $1\frac{3}{4}$ feet below the surface, were respectively 29°.8, 35°.0, and 35°.0 C.

Thus it seems that the high earth-temperature existed, on Oct. 1st, 1915, only within small "hottest portion," near the upper edge of the "heat area," wherein the trees were dead, while the rest of the space in question has practically regained its normal earth-temperature. The emanation of the warm gases injurious to the plant life had probably been commenced at the lowest end and gradually extended upwards.

As the heat area has extended upwards only about 7 metres since June (1915), when Mr. J. Sasamoto, of the Kagoshima High School, examined the locality, it is to be supposed that the heat increase and gas emanation attained their maximum activity during the first three months of March, April, and May, and also possibly already in February (1915). The interesting question of the time variation of the maximum earth-temperature in the heat area is unfortunately impossible to consider in detail, as the previous temperature determinations by different investigators were not carried on with sufficient attention. Mr. N. Maeda, of the Kagoshima Meteorological Observatory, found on July 18th, 1915, the maximum earth-temperature within the same hottest part to be 55°.0 C at the bottom of a pit about 5 feet in depth, while that obtained by Professor A. Imamura on August 13th, was about 49°$\frac{1}{2}$ C at the depth of 2 feet and under the air temperature of 31°.6 C. All these results are too low, due to the want of precaution for sufficiently preventing the external air from affecting the thermometer bulb, which was simply buried or inserted in a vertical position into the pumice mass previously dug.

58. Heat phenomena and volcanic activity. The development of earth-heat in the vicinity of Saido is by no means abnormal. As mentioned in Number 1 of the present Volume, the sea beach of the village, where still exists a mineral spring, is called Yunosaki (" hot-spring cape ") and is a likely place for the production of a new hot spring or an emanation of gases consequent to a powerful volcanic eruption in Sakura-jima. In fact, the appearance of the heat area may be taken to have been simultaneous with the 2nd stage outflow of the eastern lavas ; both being the effects of, or stress-relievings afforded to, an accumulation of the volcanic tension under the mountain consequent to the almost complete cessation of the explosions about that time. Taken in this view, the phenomenon under question, which is evidently approaching to its close, is one of the residual activities of the great recent eruption, and not a preliminary to a new one*.

Temporary fumaroles at the coast of Ushine. According to the account of Mr. H. Ōi, Chief Engineer of Kagoshima Prefecture, there was also a manifestation of increase in soil temperature in a small ravine at the coast of Ushine, some distance from the eastern end of the " contact line " or junction of the Sakura-jima lava and the former coast of Ōsumi ; there having been a slight issue of steam, such that on April 6th, 1915, the ground, when dug, had a temperature too hot to allow one's hand to be put in. This fact was apparently related to the production of the heat region in the vicinity of Saido.

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* According to Professor A. Imamura's measurements, repeated with care in Aug. 25–28, 1916, the highest earth temperature within the district in question was 63°.0 C, met with at the depth of 1.28 m. It thus seems that the maximum earth temperature did not much vary during the 11 months subsequent to the present writer's examination in Oct. 1915.

Chapter X. Notes on the Craterlets of the Anei (1779) and Bummei (1468-1476) Eruptions.

59. Comparison of old and recent craterlets. The larger explosion craterlets of the Sakura-jima eruptions in the periods of Anei (1779) and Bummei (1468–1476) are found to be not much different in magnitude from those formed in the eruption of 1914 : a fact which seems to indicate that the explosive force of the volcano did not much vary in the different outbursts during the several hundred years since the 15th century. Some of the old lava sources remain also in a well preserved condition, presenting an appearance similar to those in the recent eruption. (For the position of the craterlets and lava sources, see Pl. IX of the present Volume.)

60. Anei (1779) eruption : southern craterlets. The eruption began first from the upper craterlet on the southern or Furusato side, although the eruptive energy there was much smaller than on the north-eastern or Komen side.

Lower Lava Source. The lava source at the lower craterlet, situated 260 m above sea-level at the distance of 1250 m to the N.18°E. of the hot spring in the village of Furusato, is much similar in arrangement to that in the recent eruption formed below the eastern craterlet No. 4′, being a sort of an U-shaped cavity, 160 m in length, 50 m in width, and 20 m in depth. The lava outflow from this source, locally known as a *hoge* (" fire place "), has run down along the eastern side of that from the higher craterlet and can be clearly traced down to the coast. It seems to have run out some days after the commencement of the eruption, being coated with no special layer of pumice and ash.

Higher Craterlet. The higher craterlet, occupying the bottom of a large U-shaped old explosion basin at the southern flank of

Sakura-jima Eruption of Bummei Period (1475). Uppermost Craterlet on the S.W. Side. (Oct. 1916. F. Omori, photo.)

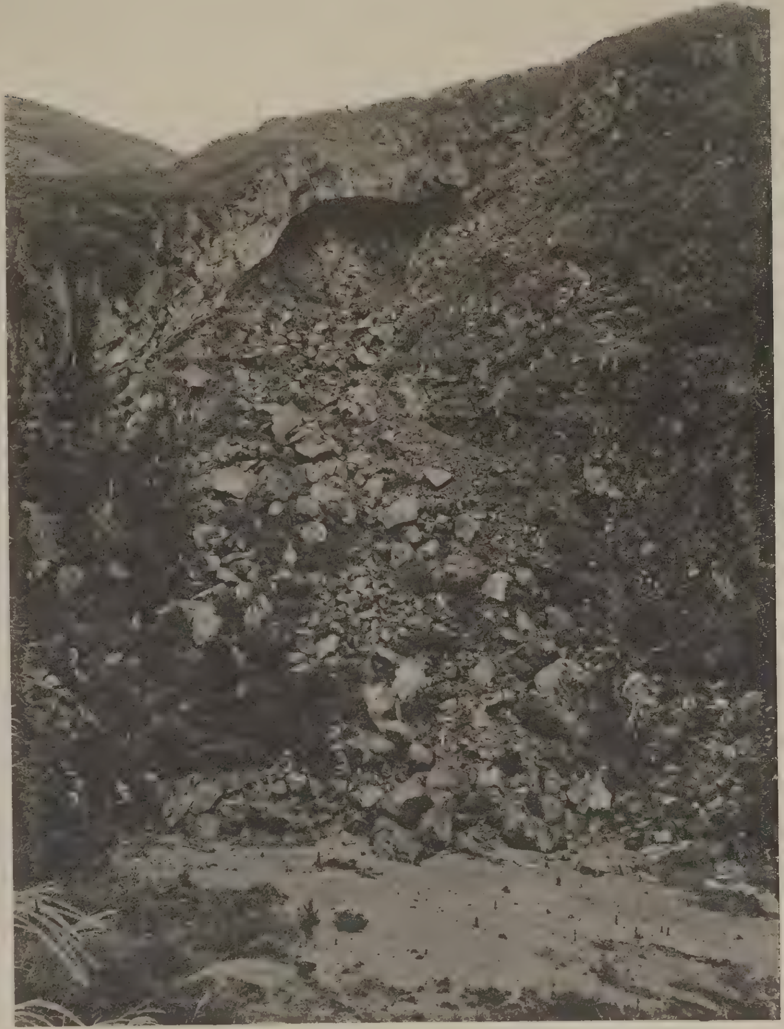

Fig. 132. The Craterlet seen from the lower or S.W. rim, showing the bottom and the N.E. inner slope.

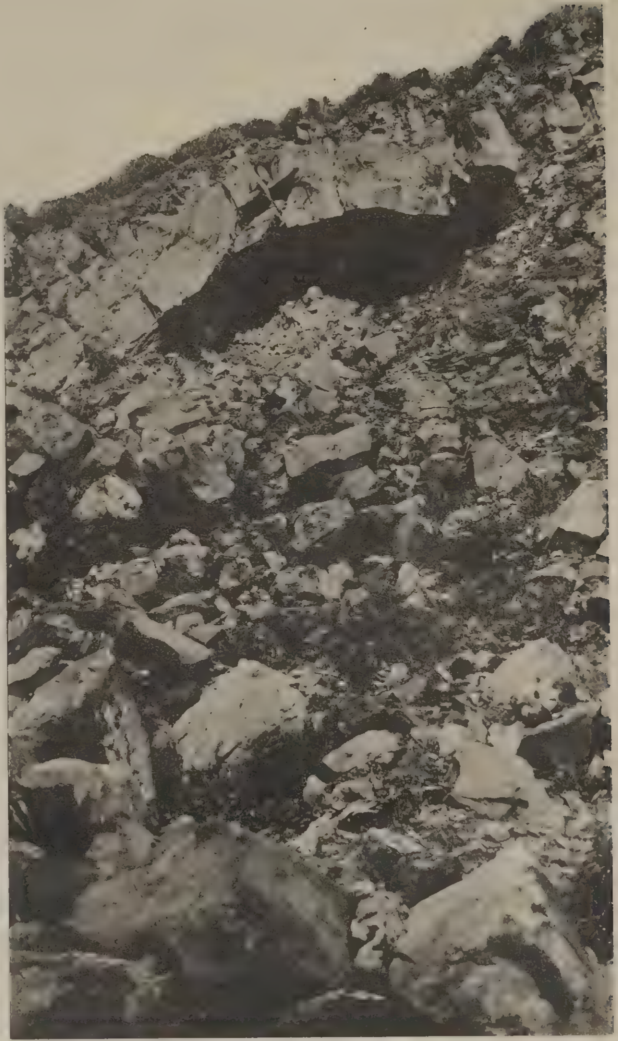

Fig. 133. Nearer View of the Lava Arch at the top of the N.E. side wall.

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Minami-dake, is situated at the height of 700 m above sea-level. The two limbs of the U, which is covered by layers of pumice and ash, still indicate traces of old dislocations and cracks, presenting an appearance somewhat similar to the disturbed grounds above the western lava sources Nos. 2 and 3 of the recent eruption. The lava from the upper craterlet progressed nearly southwards and reached the coast at the east of the hot spring of Furusato.

The main portion of the flow from the lower source took a course south slightly east and formed the new promontory of Tatsu-zaki*. A small bifurcation of the stream reached down across to the beach of Yunohama, thus leaving between the latter and Tatsu-zaki a piece of headland uncovered by the Anei lavas. This evidently marks the end of a small former ridge composing the eastern boundary of the main lava field. The length and the base width of the aggregate lower lava area are about 2.4 and 1.0 km respectively.

61. Anei (1779) eruption; north-eastern craterlets. The two large U-shaped craters or *higona* ("fire holes") at the N.E. flank of Kita-dake, whose bottom is situated at heights of about 700 m above sea-level, evidently belong to much remote epochs, their inside walls showing no exposure of compact rocks. The well preserved lava mound which is situated at the height of 550 m above sea-level and which indicates on its west side a sort of lava moraine, is probably to be taken as the source of the upper lava stream of the Anei (1779) eruption.

The second vent, situated about 1½ km to the S. slightly W. of the village of Komen, is a regular explosion craterlet of 150 m mouth diameter, with rugged rocky wall, its upper lip being 280 m above sea-level or 67 m higher than its bottom plane, which is sandy and 30 m in extension. Only a short distance to the north of, and no doubt closely related to, the cavity in question, there is the large U-shaped third craterlet with the upper rim at about 240 m above sea-level, from which descends the hilly mass marked by a series of successive transverse dislocations ; this being the origin of the lava stream, whose course is well indicated by the prominence of its sides and which, running down to the coast, formed the cape of Nishiseko-hana and the eastern boundary of the present bay of Komen.

---

* "Dragon promontory," so named from the year of the eruption, 1779, which corresponds to the sign of *tatsu* or dragon in the old Japanese calendar.

The fourth craterlet, which is situated on the gentle slope, 140 m above sea-level, and quite close to the road leading from Krokami to Komen, about 1 km to the S.E. of the latter village, is a double cavity, of which the lower compartment is the larger, with the depth of 22 m and the mouth and bottom diameters respectively of 80 and 35 m. Several other small craterlets may possibly be discovered on the N.E. eruption field, if minutely searched for. Beside the Sono-yama hill at Moto-Komen, there are two spots in the vicinity which were not buried by the Anei lava flow.

The present coastal portion of the north-eastern lava area lying out of the N.W. and S.E. straight line joining the beaches of Komen and of the small hamlet of Uranomae represents approximately the land increment caused by the eruption of 1779, the maximum seaward prolongation thus effected being some 0.9 km.

62. Bummei eruption : eastern craterlets. The eastern lava area of the Bummei (1468–1471) eruption is bounded on the southern side by the ridge of a marked "side moraine," which, being thickly covered with pumice and ash, looks like an embankment, and runs in a nearly unbroken line for the distance of 3 km, forming the northern barrier of the flat Krokami plain.

The maximum relative elevation of the side moraine over the latter is 70 m.

The northern boundary of the lava area is also marked by a sort of embankment, which is crossed near the top by a lava outflow of the Anei (1779) eruption. At the western point of convergence of the two side elevations there are the traces of at least two craterlets situated about 200 m above sea-level.

The source of the lava outflow which formed the cape of Ōmoe-zaki can clearly be identified with a small round solitary 150 m hill called Maru-yama, which stands near the road between Komen and Krokami. It is much broken up and thickly covered with a pumiceous and ashy material, and gives rise to an U-shaped ridge enclosing a mass of lava continued to the above-mentioned cape. The hamlet of Uranomae occupies a small piece of ground bounded on one side by the Anei lava and on the other by the Bummei lava of Ōmoe-zaki. About 2 km to the S.S.E. of Komen, near the junction of the Krokami and Uranomae roads, there is a sort of "dry lake" or a piece of hollow ground, about ½ km in diameter, which has not been covered by the lava outflows of the two above-mentioned periods.

63. Bummei eruption: south-western craterlets. (I.) *Craterlets of the Earlier Eruption Stage.* The craterlets belonging to the earlier period of the activity on the S.W. side of the island, in the year 1475, are at least five in number and were formed at the lower part of the S.W. side of Minami-dake along a zone, about 800 m in extension, which runs in a N.E. and S.W. direction and approximately coincides with a slope line, the highest and lowest limits being respectively 430 and 220 m above sea-level. (a). The lowest or No. 5 craterlet is a well preserved circular hole situated at the distance of 1.7 km to the N.E. of the village of Yuno. The upper rim of the slanting mouth, about 100 m in diameter, is at the height of 280 m above sea-level, or 40 m above the bottom area, now converted to a cultivated field. At a few points along the craterlet wall there are exposures of rock masses exhibiting cleavage planes similar to the lavas of the new Arimra and Ushine islets mentioned in Chapter V. 50 m below the No. 5 craterlet there is a small shallow oblong depression with bottom diameters of 40 and 16 m, which may possibly be the site of a small explosive vent. (b.) The higher rim of the craterlet No. 5 is continued to a narrow valley some 80 m in length and 40 m in width, in which the remnants of two small craterlets Nos. 4 and 3 are found, and which apparently constituted a sort of eruption fissure much similar to the one connecting the craterlets Nos. 3, 3′, 3″, and 4′ on the eastern eruption field in the great 1914 outburst. (c.) The craterlet No. 2, with its upper rim 360 m above sea-level, is about 110 m in total length and is in reality composed of two compartments. Of these the posterior one, which is the larger, is a circular hole, with flat bottom 20 m in diameter, and is surrounded by a steep wall 25 m in height. (d.) The highest or No. 1 craterlet, separated by the distance of about 90 m from the upper edge of the No. 2 craterlet, is a large oblong well-preserved hole, whose top is 430 m above sea-level and whose flat pumiceous bottom has the major and minor diameters respectively of 38 and 30 metres. The lower and upper edges of the craterlet wall are respectively 15 and 42 m higher than the bottom plane, the longitudinal extension of the mouth opening being about 116 m. As will be seen from figs. 132 and 133, the higher or N.E. side of the craterlet, whose inclination has an angle of 33°, is crowned by a solid lava arch, 19.4 m in length (chord) and 5.3 m in thickness; the opening beneath being 3.5 m in height. The under surface of the arch, exposed to about 8 m, is cracked in various direction, but indicates no irregular dislocations. A point of special interest presented by figs. 132 and 133 is their similarity to fig. 49; the arch in question being, like the covering of the compact rocky layers in the case of the recent western No. 1 craterlet (near Hikinohira), nothing else than the surface crust of a previous lava outflow. The settling down of the inner portion of a lava stream naturally produces a more or less extensive underground vacant space, this being probably one of the circumstances which favoured the formation of the western No. 1 explosive craterlets of the Bummei (1475) and Taisho (1914) eruptions actually at their respective localities. (II.) *Second Eruption Stage.* The source of the lava stream, which issued in 1476, and which formed the cape of Moe-zaki at the S.W. end of Sakura-jima seems to be the solitary 180 m hill called Kyono-tsuka (經塚) situated about 1.2 km to the north of the village of Yuno. This is composed of loose lava masses excessively broken up by deep cracks, much resembling the Maru-yama hill lava source of the Ōmoe-zaki outflow on the N.E. eruption field of the Bummei period, the Nakano-shima formed in the Anei (1779) eruption, and the western No. 3 lava source of the 1914 outburst.

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THE SAKURA-JIMA ERUPTIONS AND EARTHQUAKES. IV.

Results of the Leveling Surveys and the Kagoshima Bay Soundings made after the Sakura-jima Eruption of 1914.

By

F. OMORI, Sc. D.,

Member of the Imperial Earthquake Investigation Committee.

With Plates LXXI–LXXVI.

CHAPTER I. DEPRESSION AND ELEVATION OF THE GROUND ABOUT THE KAGOSHIMA BAY.

1. ***Precise leveling.*** By the liberality of the Imperial Academy and the good-will of the authorities of the Military Survey, a precise leveling survey along the northern coast of the Kagoshima bay was repeated in Nov. 1918–Feb. 1919, the heights of the bench marks being newly determined and compared with those measured in 1914 and 1915. The surveys in these latter years extended over the distance of 366 km. and reached from Sashiki (B.M. No. 2865) in the province of Higo to the city of Kagoshima (B.M. No. 2468), thence along the coast down to the most southerly leveling station of Hanaoka (B.M. No. 2512) in the province of Osumi, and from the town of Shikine (B.M. No. 2797) at the N.E. corner of the Kagoshima bay up to the tide gauge station of Hososhima (B.M. No. 2715) in the province of Hyuga. In the new survey, the measurement was limited to the distance of 130 km. between the neighbourhood of Ijuin (B.M. No. 2456) near the west coast of the Satsuma peninsula to the town of Hanaoka (B.M. No. 2512), and from Shikine (B.M. No. 2797) eastwards to Sueyoshi (B.M. No. 2789). According to the previous surveys the effect of the eruptive activity of Sakura-jima on the level change of the ground rapidly decreased eastwards with the distance from the coast of the Kagoshima bay, and the last-named place may in the present instance be taken as the starting point in the consideration of the depression and upheaval of the region around the Sakura-jima subsequent to the eruption of 1914.

2. *Course of the level change between* 1914 *and* 1919. The level measurement along the distance of 40 km. about the W. and N. coast of the bay between the city of Kagoshima (B.M. No. 2468) and the town of Shikine (B.M. No. 2488), and the distance of 10 km. from the latter eastwards to Fukuyama (B.M. No. 2793), was first carried on in June to Aug. 1914, then repeated in Feb. 1915, and again recently in Nov.–Dec., 1918. From Table I, which gives a comparison of the heights of the different bench marks in the three different surveys, it will be seen that, compared to the level in 1914, there was in Feb. 1915 a general depression (with the exception of the B.M. No. 2468, newly set after the eruption); while, compared to the level in the latter epoch, there was a general elevation in 1918. Thus, referred to the B.M. No. 2793 as a fixed point, which supposition certainly entails no very gross error, the relative depression in Feb. 1915 was quite marked and nearly constant at the bench marks Nos. 2481 to 2486 along the western and northern coast of the bay, amounting to 0.040 m. on the average. The elevation in 1918 relative to the level in 1915 was most distinctly shown also along the same sea coast, the

TABLE I. HEIGHT VARIATION OF THE DIFFERENT BENCH MARKS BETWEEN 1914, 1915, AND 1918.

Year. / Bench Mark.	1914	1915	1918	Difference.*			
				1914–1915		1915–1918	
No.	(August). m	(February). m	(December). m	m		m	
2793	380.744	380.744	380.744	0.000		0.000	
2794	337.010	337.008	337.011	−0.002		+0.003	
2795	254.205	254.195	254.202	−0.010		+0.007	
2796	164.267	164.249	164.266	−0.018		+0.017	
2797	88.223	88.205	88.228	−0.018		+0.023	
2488	56.847	56.826	56.850	−0.021		+0.024	
2487	3.002	2.974	3.007	−0.028		+0.033	
2486	2.624	2.585	2.644	−0.039		+0.059	
2485	4.862	4.813	4.895	−0.049		+0.082	
2484	2.939	2.890	2.986	−0.049		+0.096	
2483	(July). 11.610	11,561	11.669	−0.049		+0.108	
2482	15.434	15.386	15.495	−0.048		+0.109	
2481	46.258	46.220	46.313	−0.038		+0.093	
2480	2.644	2.612	2.698	−0.032		+0.086	
2479	9.361	9.329	9.415	−0.032	Mean:	+0.086	Mean:
2478	9.694	9.661	9.748	−0.033	−0.040	+0.087	**+0.106**
2477	4.586	4.549	4.653	−0.037		+0.104	
2476	11.441	11.401	11.525	−0.040		+0.124	
2475	5.244	5.201	5.339	−0.043		+0.138	
2474	6.198	6.143	6.311	−0.055		+0.168	
2473	5.180	5.135	5.278	−0.045		+0.143	
2472	(June). 11.027	10.984	(November). 11.113	−0.043		+0.129	
2471	9.807	9.780	9.870	−0.027		+0.090	
2470	7.525	7.512	7.579	−0.013		+0.067	
2469	2.340	2.336	2.376	−0.004		+0.040	
2468	4.360	4.370	4.396	−0.010		+0.026	

* Positive, when the height increased, and negative when it decreased.

average value being 0.106 m. Amongst the others, the bench mark No. 2474 situated at the promontory of Osaki-hana, about 10 km. to the north of the city of Kagoshima, exhibited the maximum depression of 0.055 m. and the maximum elevation of 0.168 m. in the time intervals under consideration. The mean rate of the depression was about double that of the elevation, as follows :—

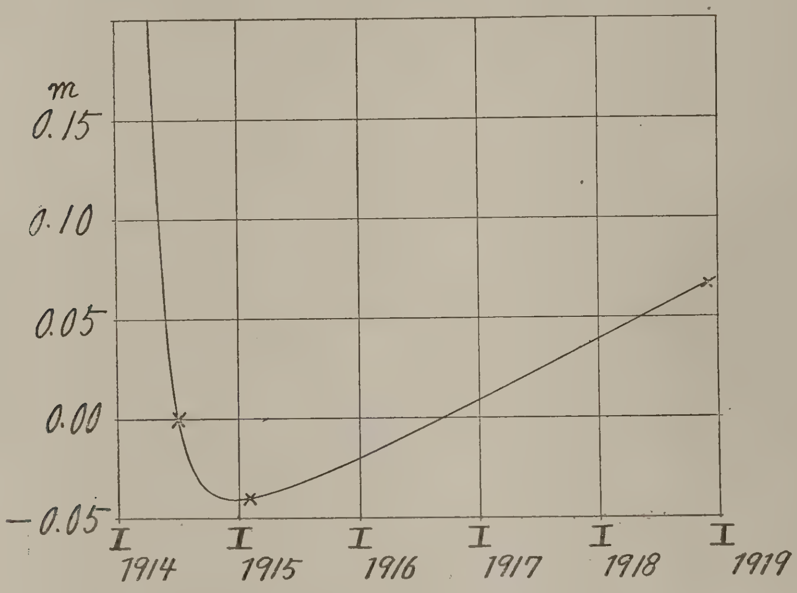

Fig. 1. Average Height Change of the Bench Marks Nos. 2471 to 2486.

Change Rate.	Depression of the Ground. July 1914—Feb. 1915.	Elevation of the Ground. Feb. 1915—Dec. 1918.
Average.	69 mm. per year	28 mm. per year.
Maximum.	94 ,, ,,	44 ,, ,,

In fig. 1 is illustrated the course of variation of the average level change between 1914 and 1918. The maximum ground depression seems to have taken place in or about October 1915.

3. *Elevation of the depressed region.* In Table IV are compared the results of the leveling in 1914–1915 with those in 1918–1919. In the older surveys, the heights of the different bench marks are referred to the B.M. No. 4 in the tide gauge room at Hososhima, measured in January 1915; it being implied that the height variation remained slight in the time interval during which the surveys were executed. This causes no very great inconvenience, as the leveling along the bay coast between the B.M. Nos. 2468 and 2488, where the height change was most marked, was finished in Feb. of the same year. In the newer survey, started from the vicinity of the town of Ijuin the heights are referred in Table IV to the B.M. No. 2456 assumed to have undergone no vertical change. This latter supposition may be inaccurate to a certain extent, as the region about Ijuin has been shaken by several strong earthquakes previous to the eruption. In Table II the total amount of the height variation of the different bench marks during the 4 years 1914–5 to 1918–9 is given with reference to the B.M. No. 2789 at the eastern extremity as a fixed point. According to Table II the elevation was slight and nearly constant, with the average amount of 53 mm., across the Satsuma peninsula from the B.M. No. 2469 at Kagoshima to the B.M. No. 2456 at Ijuin. It was also small at the N.E. corner of the bay coast, with the amount of 27.5 mm. at B.M. No. 2796, thence quickly decreasing toward the east. Along the whole N.E. coast of the Kagoshima bay, for the distance of 50 km. between B.M. No. 2512 on the south, the elevation was slight and, with a few exceptions, nearly constant, the mean amount being 35 mm. On the other hand, the elevation was considerable for the distance of about 30 km. along the coast from a little to the north of Kagoshima to the vicinity of Kokbu, between the bench marks

TABLE II. HEIGHT CHANGES OF THE DIFFERENT BENCH MARKS AROUND THE KAGOSHIMA BAY AFTER THE GREAT SAKURA-JIMA ERUPTION OF 1914: AMOUNT OF RECOVERY OF THE DEPRESSED REGION IN THE COURSE OF ABOUT 4 YEARS BETWEEN JUNE 1914—SEPT. 1915 AND NOV. 1918—FEB. 1919.

No. of Bench Mark.	Amount of Elevation.	Remark.	No. of Bench Mark.	Amount of Elevation.	Remark.
	mm			mm	
2456	55.4	Amount of Elevation nearly constant: mean value = 53 mm.	2487	42.7	With the exception of a few points, the amount of elevation nearly constant: mean value = 35 mm.
2457	55.0		2488	34.6	
2458	56.1		2797	33.0	
2459	56.8		2489	13.3	
2460	61.9		2490	12.9	
2461	53.9		2492	37.2	
2462	56.5		2493	46.1	
2463	57.5		2495	40.3	
2464	53.0		2496	37.4	
2465	51.8		2497	8.6	
2466	52.1		2498	40.0	
2467	39.8		2499	−1.5	
2468	37.3		2500	39.0	
2469	50.9		2501	48.7	
			2502	38.6	
2470	77.3	The elevation very conspicuous.	2503	31.6	
2471	100.9		2504	25.7	
2472	139.1		2505	28.7	
2473	152.9		2506	32.1	
2474	178.4		2507	37.0	
2475	148.4		2508	38.4	
2476	134.0		2509	39.6	
2477	113.4		2510	42.6	
2478	96.7		2511	49.4	
2479	96.7		2512	49.3	
2480	96.2				
2481	103.2		2796	27.5	Amount of elevation rapidly decreased with the distance from the N.E. coast of the Kagoshima bay.
2482	119.3		2795	16.7	
2483	118.1		2794	13.4	
2484	106.9		2793	9.5	
2485	92.8		2792	3.1	
2486	68.6		2791	0.6	
			2790	−0.5	
			2789	0.0	

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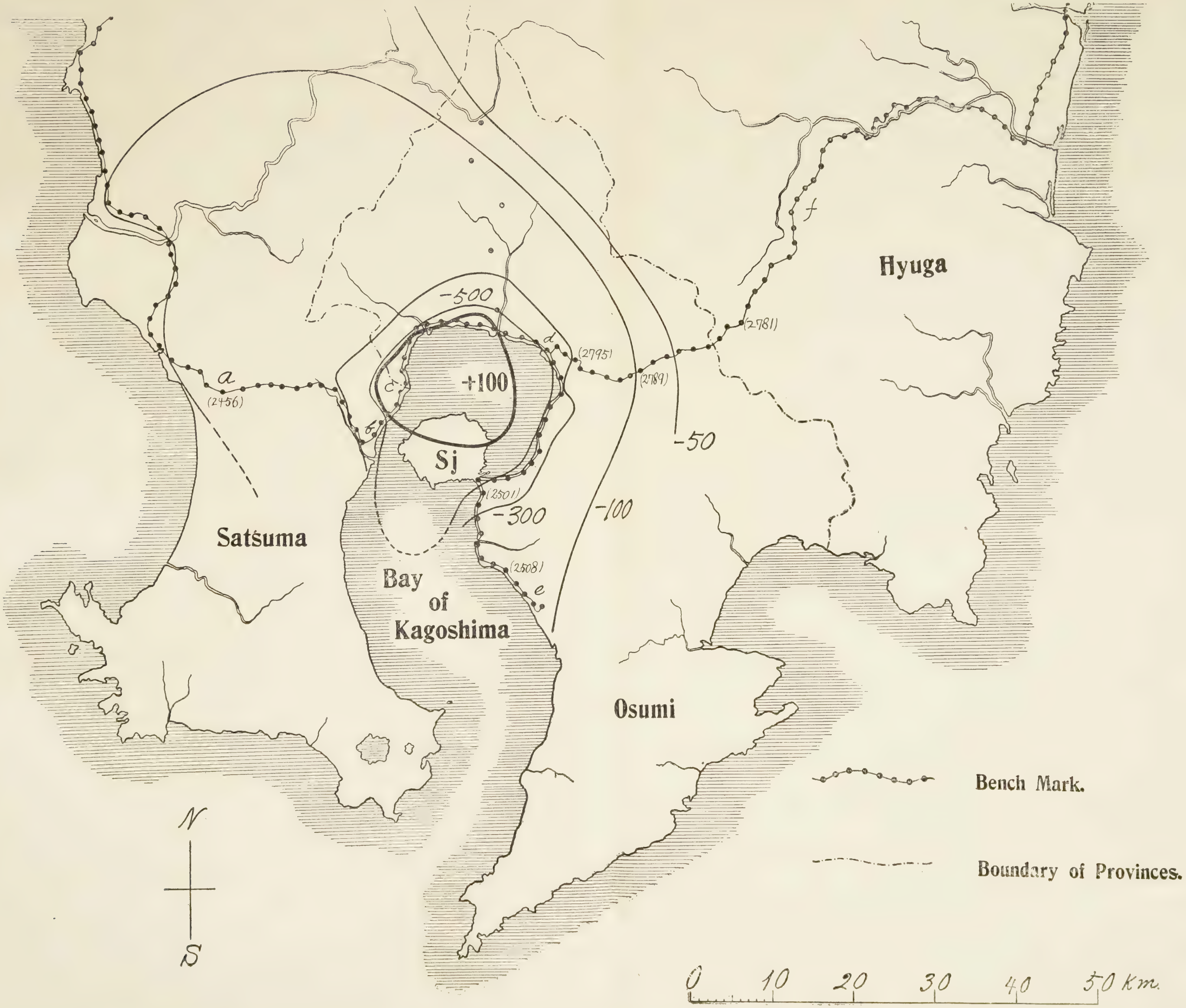
Fig. 2. Map of Sakura-jima and the Vicinity, showing the Depression of the Ground after the Eruption of 1914 and the Subsequent Upheaval.

(−50), (−100), (−300), and (−500) curves indicate the boundaries of the areas whose depressions after the Eruption were, relative to 1894, respectively 50, 100, 300, and 500 mm.

Pl. LXXI.



The thick (+100) curve indicates the area within which the restitution process resulted in the upheaval of over 100 mm. in the course of the 4 years 1914-5 to 1918-9. a b c d e f.... Line of Precise Leveling.

a... B. M. No. 2456, at Ijuin. b.... B. M. No. 2469, in the city of Kagoshima
c... B. M. No. 2474, at Osaki-hana, where the height changes were most marked

Nos. 2470 and 2486, with the mean amount of 114 mm. This region must, therefore, be much nearer to the origin of the upheaval than the remaining part of the coast; the Osaki-hana promontory, with the maximum elevation of 178.4 mm. being evidently at the shortest radial distance. The *iso-elevation* curve of 100 mm. drawn by interpolations from the results of the observations, is, as shown in fig. 2, an irregular circle about 17 km. in diameter, whose centre is situated under the sea, about 5 km. to the east

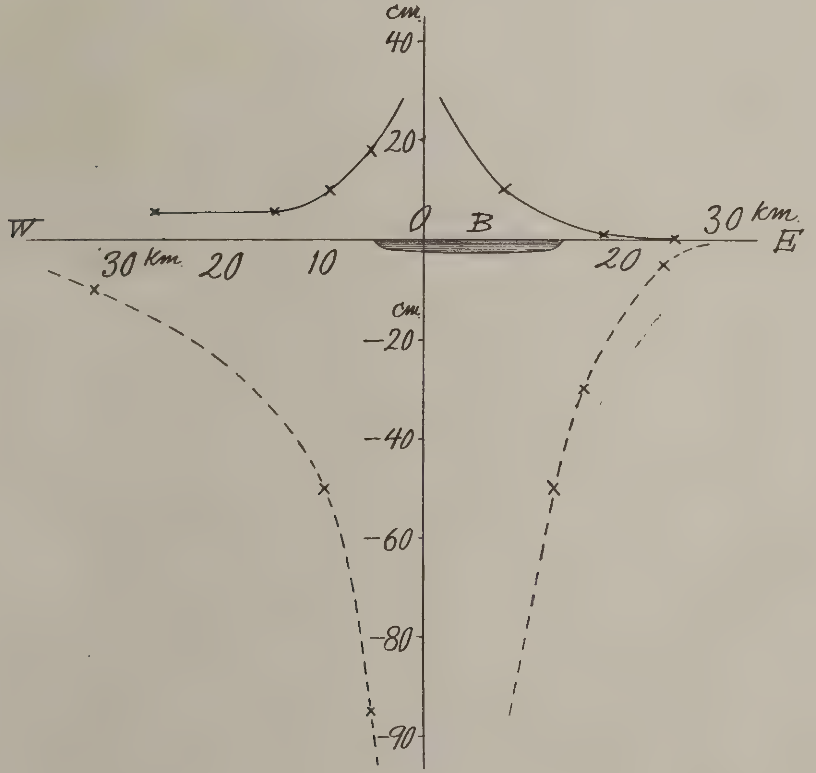


Fig. 3. Sectional Diagram representing the amount of the Depression caused by the Sakura-jima Eruption and of the subsequent Upheaval in an E.W. direction at varying radial distances from the Centre (0) of the Level Changes. The depression is measured downwards, and the elevation upwards, along the vertical axis drawn through 0.

B....... Inner Kagoshima Bay.

TABLE III. LEVEL CHANGES ALONG THE E.W. LINE THROUGH THE UPHEAVAL CENTRE.

Distance.	Elevation in 1918-1919.	Distance.	Depression in 1914–1915.
To the West of the Centre of Elevation.			
5.4 km.	+178.4 mm.	5.4 km.	−949 mm.
9.5	+100	10	−550
15–27	+ 55	33	−100
To the East of the Centre of Elevation.			
8 km.	+100 mm.	13 km.	−500 mm.
18	+ 10	16	−300
25	+ 0	24	− 50

of the Osaki-hana and 4 km. from the northern coast of Sakura-jima. It will be noticed that this area of marked elevation is nearly concentric with, and of an extension not widely inferior to, the *iso-depression* curve of 500 mm. relating to the time interval of June 1914—Feb. 1915, given in Pl. XXIX of this Volume and reproduced in fig. 2. Further the two curves nearly coincide with, or are not very much distant from, the coast line of the bay to the north of Sakura-jima. In other words, the present area of maximum elevation is the same as that of the previous maximum depression; both approximately coinciding with the bay coast, which is consequently to be regarded as the boundary of the region specially susceptible to the depression and elevation caused by eruption of the neighbouring volcano of Sakura-jima, or the joint activity of Sakura-jima and Kirishima. The amount of the depression in 1914–1915 was some 5 times greater than that of the subsequent recovery, or elevation. Fig. 2 and fig. 3, which latter gives a diagrammatic representation of the level variations along the E.W. line drawn through the centre of the upheaval, seem to indicate that, towards the east, both the depression and the elevation were reduced to a comparatively slight degree already at the distance of 30 km. Towards the west, however, these changes continued to be distinct to a much greater distance.

TABLE IV. HEIGHT OF THE DIFFERENT BENCH MARKS AROUND THE KAGOSHIMA BAY IN 1914—1915 AND IN 1918—1919.

Bench Mark.			Leveling, 1914-15.		Leveling, 1918-19.		Difference.
Locality.		No.	Month, Year.	Height.	Date.	Height.	
[Province of Satsuma.]				metre.	1918.	metre.	metre.
Shimo-Ijuin.	日置郡下伊集院村	2456	VI, 1914.	55.8702	XI, 16	55.8702	0.0
„	„ „	2457	„	64.3488	18	64.3484	−0.0004
„	„ „	2458	„	81.8929	„	81.8936	+0.0007
„	„ „	2459	„	104.6832	19	104.6846	+0.0014
„	„ „	2460	„	101.1277	„	101.1342	+0.0065
Ishiki.	鹿兒島郡 伊敷村	2461	„	143.3369	17	143.3354	−0.0015
„	„ „	2462	„	105.4131	21	105.4142	+0.0011
„	„ „	2463	„	65.8109	22	65.8130	+0.0021
„	„ „	2464	„	26.5141	23	26.5117	−0.0024
„	„ „	2465	„	17.5973	„	17.5937	−0.0036
„	„ „	2466	„	13.9173	28	13.9140	−0.0033
Kagoshima.	鹿兒島市 草牟田町	2467	„	7.3953	30	7.3797	−0.0156
„	„ 平野町	2468	II, 1915.	4.3695	27	4.3514	−0.0181
„	„ 小川町	2469	„	2.3351	30	2.3310	−0.0045
Yoshino.	鹿兒島郡 吉野村	2470	„	7.5119	29	7.5338	+0.0219
„	„ „	2471	„	9.7798	„	9.8253	+0.0455
„	„ „	2472	„	10.9840	28	11.0677	+0.0837
„	„ „	2473	„	5.1354	XII, 6	5.2329	+0.0975
„	„ „	2474	„	6.1434	7	6.2664	+0.1230
„	„ „	2475	„	5.2009	6	5.2939	+0.0930
[Province of Osumi.]							
Shigetomi.	始良郡 重富村	2476	„	11.4009	7	11.4795	+0.0786

Bench Mark.				Leveling, 1914-15.		Leveling, 1918-19.		Difference.
Locality.			No.	Month, Year.	Height.	Date.	Height.	
[Province of Osumi.]								
Shigetomi.	姶良郡	重富村	2477	II, 1915.	metre. 4.5496	1918. XII, 5	metre. 4.6076	metre. +0.0580
Chosa.	,,	帖佐村	2478	,,	9.6614	5	9.7027	+0.0413
Kajiki.	,,	加治木町	2479	,,	9.3290	10	9.3703	+0.0413
,,	,,	,,	2480	,,	2.6123	10	2.6531	+0.0408
,,	,,	,,	2481	,,	46.2198	10	46.2676	+0.0478
Nishi-Kokbu.	,,	西國分村	2482	,,	15.3861	14	15.4500	+0.0639
,,	,,	,,	2483	,,	11.5611	14	11.6238	+0.0627
,,	,,	,,	2484	,,	2.8899	13	2.9414	+0.0515
Higashi-Kokbu.	,,	東國分村	2485	,,	4.8130	13	4.8504	+0.0374
,,	,,	,,	2486	,,	2.5855	16	2.5987	+0.0132
Shikine.	,,	數根村	2487	,,	2.9744	16	2.9617	−0.0127
,,	,,	,,	2488	,,	56.8259	16	56.8051	−0.0208
Fkuyama.	,,	福山村	2489	VIII, 1914.	2.2544	1919. I, 4	2.2123	−0.0421
,,	,,	,,	2490	,,	5.7590	4	5.7165	−0.0425
Ushine.	肝屬郡	牛根村	2491	,,	2.6216	5	5.6171	newly set.
,,	,,	,,	2492	,,	9.3017	5	9.2835	−0.0182
,,	,,	,,	2493	,,	6.2465	13	6.2372	−0.0093
,,	,,	,,	2494	,,	14.2079	8	5.8552	newly set.
,,	,,	,,	2495	,,	2.1600	10	2.1449	−0.0151
,,	,,	,,	2496	,,	8.4140	11	8.3960	−0.0180
,,	,,	,,	2497	VII, 1914.	5.4574	11	5.4106	−0.0468
	,,	,,	2498	,,	4.0482	19	4.0328	−0.0154
	,,	,,	2499	,,	8.2395	22	8.1826	−0.0569
Tarumizu.	,,	垂水村	(A)	,,	12.2759	22	12.2595	−0.0164
,,	,,	,,	2501	,,	6.0637	23	6.0570	−0.0067
,,	,,	,,	2502	,,	3.0201	25	3.0033	−0.0168
,,	,,	,,	2503	,,	2,9455	26	2.9217	−0.0238
,,	,,	,,	2504	,,	4.1481	28	4.1184	−0.0297

Bench Mark.			Leveling, 1914–15.		Leveling, 1918–19.		Difference.
Locality.		No.	Month, Year.	Height.	Date.	Height.	
[Province of Osumi.]				metre.	1919.	metre.	metre.
Tarumizu.	肝屬郡 垂水村	2505	VII, 1914.	3.0159	I. 28	2.9892	−0.0267
„	„ „	2506	IX, 1914.	5.4960	27	5.4727	−0.0233
„	„ „	2507	„	3.7853	27	3.7669	−0.0184
Shinzyo.	„ 新城村	2508	„	3.6367	29	3.6197	−0.0170
„	„ „	2509	„	4.1233	II. 1	4.1075	−0.0158
„	„ „	2510	„	7.6411	1	7.6283	−0.0128
Hanaoka.	„ 花岡村	2511	„	17.4511	1	17.4451	−0.0060
„	„ „	2512	„	128.2957	1	128.2896	−0.0061
Shikine.	姶良郡 敷根村	2797	II, 1915.	88.2051	1918. XII. 20	88.1827	−0.0224
Fkuyama.	„ 福山村	2796	„	164.2492	19	164.2213	−0.0279
„	„ „	2795	„	254.1953	18	254.1566	−0.0387
„	„ „	2794	„	337.0075	27	336.9655	−0.0420
„	„ „	2793	„	380.7444	26	380.6985	−0.0459
„	„ „	2792	XII, 1914.	367.3154	26	367.2631	−0.0523
„	„ „	2791	„	307.8617	25	307.8069	−0.0548
„	„ „	2790	„	297.7945	25	297.7386	−0.0559
Sueyoshi.	噌唹郡 末吉村	2789	„	292.1460	29	292.0906	−0.0554

CHAPTER II. SEA-LEVEL CHANGE AT KAGOSHIMA.

4. *Sea-level change after* 1914. The great Sakura-jima eruption of 1914 was followed by abnormal changes in the height of the mean sea-level of the Kagoshima bay; the course of the variation during the first two years having already been considered in Part 2 of the present Volume. In the following §§ I give a few remarks on the results of the tide gauge observations carried on by the Civil Engineering Department of the Kagoshima Prefecture at the Kogoshima harbour during the 6 years 1914 to 1919.

5. *Maximum daily tide range.* According to Table V, the maximum daily tide range in the different months after the eruption varied, in the yearly mean, between 9.86 *shaku** (=2.99 m.) and 10.01 *shaku* (=3.03 m.) with the general average value of 9.93 *shaku* (=3.01 m.). These values are almost exactly identical

TABLE V. DAILY MAXIMUM TIDE RANGE AT THE KAGOSHIMA HARBOUR BEFORE BND AFTER THE GREAT SAKURA-JIMA ERUPTION OF 1914. (In *shaku.*)

Year. / Month.	Before the Eruption.		After the Eruption.					
	1903	1904	1914	1915	1916	1917	1918	1919
I	10.7	10.4	—	—	10.5	10.7	9.9	9.35
II	10.1	10.9	8.3	9.7	10.4	10.25	10.5	9.8
III	9.2	10.2	10.6	8.9	9.7	9.55	10.0	9.8
IV	9.7	9.6	10.4	10.6	9.8	9.65	10.3	10.7
V	10.2	9.8	—	10.2	10.2	9.45	10.3	11.15
VI	10.1	10.0	—	10.0	10.0	9.45	9.4	10.25
VII	10.6	10.1	—	9.8	10.4	10.2	9.75	9.6
VIII	10.1	10.4	—	10.7	10.1	10.2	9.75	9.3
IX	9.2	10.1	—	8.6	9.5	10.0	9.7	9.35
X	9.1	9.9	—	9.6	8.5	9.95	10.4	10.3
XI	9.0	9.6	—	10.0	9.7	9.9	10.1	10.6
XII	9.9	9.6	—	10.3	10.4	9.5	10.05	10.3
Mean.	9.83	10.05	9.77	9.86	9.93	9.90	10.01	10.04
General Mean.	9.94		9.95					

---

* 1 *shaku* = 0.994 foot = $\frac{1}{3.3}$ × 1 metre.

with those for the years previous to the eruption, the average range in question during 1903 and 1904 being 9.94 *shaku* (=3.01 m.).

6. *Annual variation of mean sea-level.* The Kagoshima bay mean sea-level relative to the coast attained its maximum elevation at the latter part of the year of the great eruption, 1914, after which it began to be lowered somewhat. As

TABLE VI. MEAN MONTHLY SEA-LEVEL HEIGHT AT THE HARBOUR OF KAGOSHIMA BEFORE AND AFTER THE SAKURA-JIMA ERUPTION OF 1914.

Month.	Before the Eruption. 1903–1905.		After the Eruption.						
	Mean.	Mean (Relative).	1915	1916	1917	1918	1919	Mean.	Mean (Relative).
	shaku.	*shaku.* mm.	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.* mm.
I	5.29	0.28 = 84.8	—	6.65	6.81	6.35	6.82	6.66	0.00 = 0.0
II	5.01	0.00 = 0.0	7.26*	6.80	6.46	6.67	6.99	6.73	0.07 = 21.2
III	5.28	0.27 = 81.8	7.26*	6.77	6.35	6.62	7.06	6.70	0.04 = 12.1
IV	5.24	0.23 = 69.7	7.07	6.94	6.55	6.55	6.88	6.80	0.14 = 42.4
V	5.23	0.22 = 66.7	7.04	7.10	6.75	6.75	6.83	6.89	0.23 = 69.7
VI	5.60	0.59 = 178.8	7.39	7.16	7.10	6.79	7.33	7.15	0.49 = 148.5
VII	5.95	0.94 = 284.8	7.49	7.40	7.22	7.40	7.35	7.37	0.71 = 215.1
VIII	6.04	1.03 = 312.1	7.76	8.01	7.61	7.58	7.74	7.74	1.08 = 327.2
IX	6.11	1.10 = 333.3	7.69	7.49	7.55	7.93	7.47	7.63	0.97 = 293.9
X	5.94	0.93 = 281.8	7.54	7.48	7.48	7.63	7.36	7.50	0.84 = 254.5
XI	5.35	0.34 = 103.0	7.34	7.39	6.85	7.13	7.05	7.15	0.49 = 118.5
XII	5.13	0.12 = 36.4	6.82	7.05	6.46	6.85	6.64	6.76	0.10 = 30.3
Mean Level.	5.51	—	*shaku.* 7.33	*shaku.* 7.19	*shaku.* 6.93	*shaku.* 7.02	*shaku.* 7.13	*shaku.* 7.13	—
Mean Barometric Pressure.			mm. 761.87	mm. 762.29	mm. 762.28	mm. 762.65	mm. 761.08	—	—
Mean Level With Bar. Correction.			*shaku.* 7.41	*shaku.* 7.28	*shaku.* 7.02	*shaku.* 7.13	*shaku.* 7.22	—	—

* Excluded in the deduction of the mean monthly value in the annual variation, as the sea-level elevation was then markedly much greater than in the other years.

will be seen, however, from Table VI, the sea-level decrease ceased to be distinctly marked since February 1915. Consequently the average height for the different months of the year deduced from the tide gauge observations during nearly the five years

Annual Variation of the Mean Sea-level at Kagoshima and Hososhima.

(Averaged from the observations during the 5 years after the Eruption, 1915–1919.)

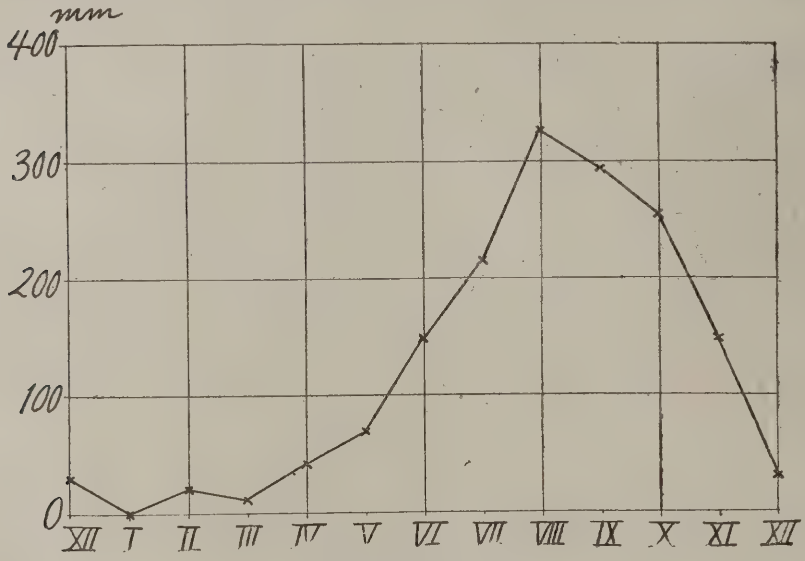


Fig. 4. Kagoshima.

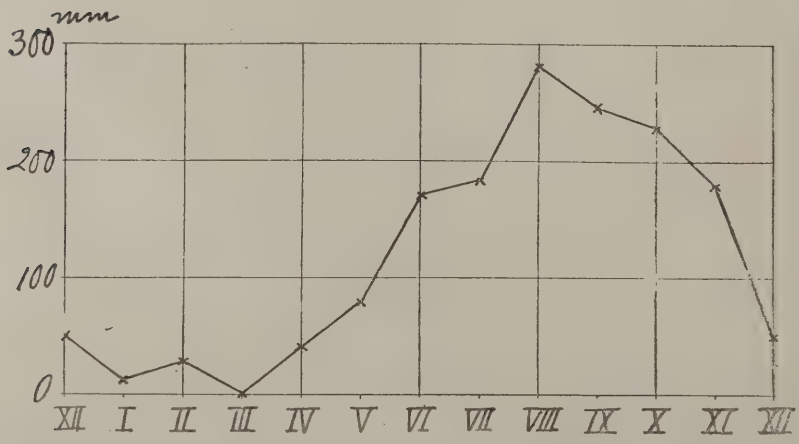


Fig. 5. Hososhima.

from April 1915 to Dec. 1919 will not be affected by the secular sea-level lowering to any considerable extent. Thus according to Table VI and fig. 4, the mean monthly sea-level in the time interval under consideration subsequent to the eruption was lowest in December, January, February, March, and April, and highest in August and September; the maximum amount of the fluctuation or the extent of the annual variation in the mean height of the sea surface being 1.08 *shaku*=0.33 m.

It will be noted that the general course and the amount of the annual variation subsequent to the eruption as above mentioned is very much similar to those for the years previous to the latter. Thus, in 1903 and 1905, the mean monthly sea-level was also highest in August and September, the range of the annual variation being 1.1 *shaku*=0.33 m.

The annual variation of the sea-level height at the tide gauge station of Hososhima during the corresponding time interval was almost perfectly identical with that at Kagoshima here considered. (See fig. 5 and Table X.)

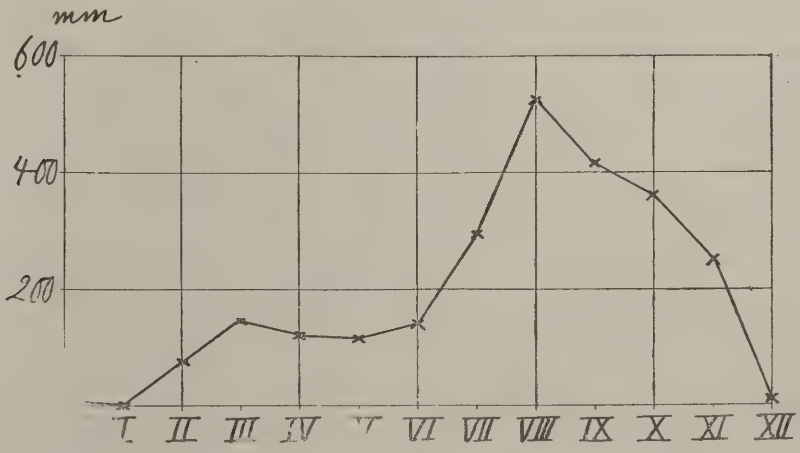


Fig. 6. Annual Variation of the Mean High-Water Level at Kagoshima.
(Averaged from the observations during the 6 years after the Eruption, 1914–1919.)

TABLE VII. MAXIMUM MONTHLY SEA-LEVEL HEIGHT AT THE HARBOUR OF KAGOSHIMA, BEFORE AND AFTER THE SAKURA-JIMA ERUPTION OF 1914.

Year. / Month.	Before the Erupt. 1903–5.	After the Eruption.							
		1914	1915	1916	1917	1918	1619	Mean.	Mean (relative)
	shaku.	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.* mm.
I	10.5	—	11.3	11.4	11.6	11.2	11.40	11.38	0.00 = 0.0
II	10.5	10.8	12.1	11.8	11.5	11.7	11.85	11.63	0.25 = 75.8
III	10.4	12.2	11.8	11.8	11.5	11.7	12.15	11.86	0.48 = 145.5
IV	10.3	11.8	12.0	11.6	11.5	11.5	12.25	11.78	0.40 = 121.2
V	9.9	11.5	11.8	11.9	11.6	11.8	11.95	11.76	0.38 = 115.1
VI	10.6	11.7	12.2	12.2	11.5	11.3	12.20	11.85	0.47 = 142.4
VII	10.8	12.1	12.1	12.3	12.3	13.25	12.05	12.35	0.97 = 293.9
VIII	10.8	13.5	12.7	13.0	12.8	12.8	13.85	13.11	1.73 = 524.2
IX	11.2	12.7	13.1	12.3	12.9	12.9	12.55	12.74	1.36 = 412.1
X	11.0	12.9	12.5	12.5	12.6	12.65	12.35	12.58	1.20 = 363.6
XI	10.3	12.2	12.5	12.3	12.1	11.8	12.30	12.20	0.82 = 248.5
XII	9.8	11.3	11.6	11.7	10.9	11.3	11.65	11.41	0.03 = 9.1
Mean.	10.51	12.06	12.14	12.07	11.90	11.99	12.21	12.05	—

7. *Annual variation of maximum high water level.* According to Table VII, the greatest spring tide in the Kagoshima harbour during the first 5 years was 13.5 *shaku* and occurred in August of the year of the eruption. In 1919, six years after the latter event, a still higher level of 13.85 *shaku* was reached in August. Taking the averages from the six years, 1914 to 1919, the high water was lowest in December, January, and February, and highest in August and September; the amount of the annual fluctuation of the monthly value being 1.73 *shaku* = 0.52 m. Although the high tide level is naturally much affected by the barometric pressure existing at the time of the springs, the course of its annual variation is on the whole much similar to that of the mean monthly sea-level. (See fig. 6.)

8. ***Tide range and the subsidence of ground.*** The remarkable subsidence of the ground in Sakura-jima and about and under the northern portion of the Kagoshima bay, which set in after recent great eruption, is doubtless to be attributed to the great amount of the lava outflow and of the pumice and ash ejection, whose volume aggregates to 2.2 c. km., or 1/12th of that of the whole mountain. It is likely that after the eruption of 1914 a partial void, or a state more or less equivalent to a void, existed under the volcano on the region neighbouring it, and it might be supposed that such a condition would favour an increase in the range of the daily tide motion and of the annual variation of the mean monthly sea-level. This was, however, not the case; there being, according to the two preceding §§, no apparent difference of the sort under consideration before and after the great outburst. The conclusion is that the earth's crust, or rather the surface ground, about the Sakura-jima was, even immediately after the eruption, rigid enough to be thrown into daily or annual vertical oscillation by the tidal water, at least not to such an extent as would be revealed by the ordinary tide gauge observations.

9. ***Average height of Kagoshima sea-level.*** In Table VIII are compared the average heights of the sea-level at Kagoshima (referred to the bench-mark No. 2469 at Ogawa-machi, in Kagoshima) for the different years before and after the eruption. (ii) and (iv) give the annual means respectively of the monthly mean and of the monthly high tide level; while (i) gives the mean sea-level during the three months of February, March, and April, during which the sea-level is lowest and nearly constant. (iii) is

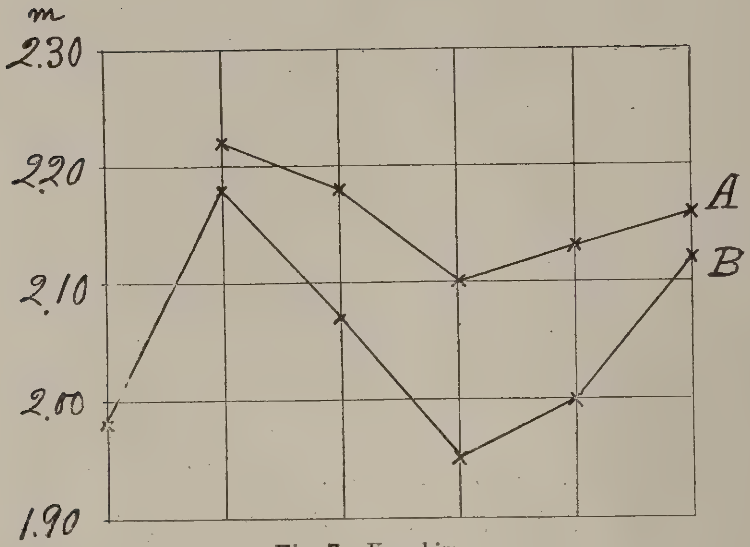


Fig. 7. Kagoshima.

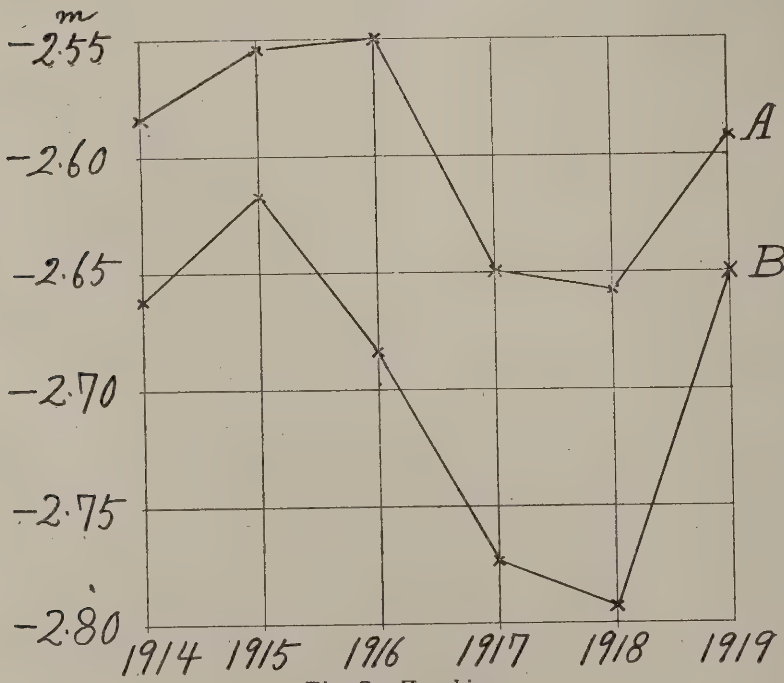


Fig. 8. Hososhima.

Yearly Variation of the Mean Sea-level, 1914–1919.

(A) Annual mean height. (B) Mean height in Feb., March, and April.

TABLE VIII. AVERAGE SEA-LEVEL BEFORE AND AFTER THE ERUPTION.

Deduction of the Mean.	Before the Eruption.	After the Eruption.							Water Level Elevation.
	(I) 1903-1905.	1914.	1915.	1916.	1917.	1918.	1919.	(II) Mean.	(II)-(I)
Monthly mean sea-level:—	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*
(i). Feb., March, April.	**5.18**	6.55	7.20	6.84	6.45	6.61	6.98	**6.77**	1.59
(ii). Whole Year.	**5.51**	—	7.33	7.19	6.93	7.02	7.18	**7.13**	1.62
(iii). *Do.* with barometric correction.	**5.63**	—	7.41	7.28	7.02	7.13	7.22	**7.21**	1.59
Monthly highest sea-level:— (iv). Whole Year.	**10.51**	11.98	12.14	12.07	11.90	11.99	12.26	**12.06**	1.55

TABLE IX. MEAN MONTHLY BAROMETRIC HEIGHT AT KAGOSHIMA, REDUCED TO SEA-LEVEL, IN MM.

Year. \ Month.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Mean.
1915	767.91	763.96	764.84	762.63	759.80	758.90	757.89	753.81	757.88	761.59	766.90	766.27	761.87
1916	768.24	763.38	765.11	763.47	760.40	757.96	758.01	754.69	760.61	763.77	765.44	766.45	762.29
1917	767.69	764.99	765.33	760.70	759.99	757.75	758.87	757.54	760.53	761.86	766.58	765.47	762.28
1918	767.32	767.90	764.91	762.76	760.20	758.67	755.1	758.8	758.3	763.8	766.87	766.72	762.65
1919	766.29	765.49	763.69	762.17	760.88	755.82	757.6	761.2	758.20	762.03	764.15	766.27	761.98
Mean.	767.49	765.14	764.78	762.35	760.25	757.82	757.49	757.21	759.10	762.61	765.99	766.24	762.21

the same as (ii) with a barometric correction, i.e., reduced to the case of the pressure of 760 mm., supposing 1 mm. barometric decrease to be compensated by the sea water rise of 13.3 mm. (See figs. 7 and 8.) The general average water level during the 6 years following the eruption was about 1.6 *shaku* (=0.49 m.) higher than in 1903–1905.

10. ***Comparison with the mean sea-level at Hososhima.*** For the sake of reference let us here examine the contemporaneous changes in the mean sea-level at the tide gauge station of Hososhima, which is situated along the Pacific coast of the neighbouring province of Hyuga to the N. E. of the Sakura-jima. The average height in question was −2.541 m. in the years (i) 1903 to 1905, and −2.603 m. in the interval (ii) of 1915 to 1919, as shown in Table X. Thus the average sea-level in the period

TABLE X. MEAN SEA-LEVEL AT HOSOSHIMA.

Year.	Mean sea level.
	(−) m.
1903	2.531
1904	2.551
1905	2.540
1906	2.557
1907	2.574
1908	2.556
1909	2.575
1910	2.598
1911	2.614
1912	2.597
1913	2.583
1914	2.584

Year. / Month.	1915	1916	1917	1918	1919	Mean.	Mean (relative).
	(−) m.	(−) m.	(−) m.	(−) m.	(−) m.	(−) m.	(+) mm.
I	2.666	2.702	2.648	2.852	2.702	2.714	12
II	2.620	2.675	2.748	2.786	2.662	2.698	28
III	2.635	2.723	2.813	2.815	2.646	2.726	0
IV	2.597	2.654	2.758	2.777	2.641	2.685	41
V	2.604	2.572	2.706	2.713	2.642	2.647	79
VI	2.489	2.508	2.580	2.684	2.517	2.556	170
VII	2.532	2.492	2.590	2.579	2.524	2.543	183
VIII	2.403	2.325	2.474	2.539	2.483	2.445	281
IX	2.413	2.490	2.529	2.420	2.555	2.481	245
X	2.459	2.455	2.524	2.507	2.543	2.498	228
XI	2.539	2.430	2.662	2.560		2.548	178
XII	2.689	2.577	2.767	2.669		2.676	50
Mean.	2.554	2.550	2.650	2.658	2.592		

(ii) was 2.603–2.541 = 0.062 m. lower than in the period (i). If this depression ought to exist independently of the Sakura-jima eruption also for the Kagoshima bay, the sea-level at the coast of the latter may be assumed to have experienced in reality an elevation of 0.49 m. + 0.06 m. = 0.55 m. nearly between the two time intervals under consideration.

11. *Variation of the yearly mean sea-level.* As illustrated in fig. 7, the mean sea-level at Kagoshima for February, March, and April, which was only 6.55 *shaku* in 1914, reached the maximum height of 7.20 *shaku* in 1915, thence being reduced to a minimum of 6.45 *shaku* in 1917. Thereafter the mean level was again elevated, reaching the height of nearly 7.0 *shaku* in 1919. The height of the mean yearly sea-level also indicated a similar course of variation with a minimum in 1917. The reduction to the standard barometric pressure of 760 mm., which gives only a slight modification to the mean sea-level, does not much alter the relative heights of the latter for the different years.

CHAPTER III. CHANGE IN THE DEPTH OF THE KAGOSHIMA BAY BEFORE AND AFTER THE ERUPTION OF 1914.

12. *Hydrographic surveys of Kagoshima bay.* According to the precise leveling carried on in 1914–1915 around the northern or inner portion of the Kagoshima bay, the centre of the disturbance, where the depression might amount to 1 or 2 fathoms, was unmistakably located in the latter. I asked, therefore, Rear-Admiral Kamimra, hydrographer of the Navy, to make new soundings for the purpose of ascertaining the changes in the water depth due to the eruption of Sakura-jima. Although the depression of the sea bottom formed no cause of inconvenience to the navigation, the work of completely resounding the bay, which was a task of highest scientific importance to be solved adequately nowhere else, was taken up by the Navy and very minutely carried into execution in 1917, a preliminary survey having been made off the S. W. coasts of Sakura-jima already in the latter part of 1914. The number of the soundings taken in the first hydrographic survey of the Kagoshima bay, executed in 1906, was far smaller than that on the recent occasions. Hence the comparison of the old and new depths of the water at different points of the bay is to be regarded as being only approximately correct. At those portions of the bay, however, where the sea bottom is flat and the depth does not much vary from place to place, the amount of the relative depression or elevation can be ascertained with a fair degree of accuracy. It is hereby to be remarked that the water depth given on a chart is expressed in fathoms, the amount below one fathom being altogether not taken into account. Thus the comparison in the present instance, based on the examination of the old printed charts and the new detail manuscript charts of the Kagoshima bay may be subject to some error, ranging between 0 and 5 feet.

13. *Depth of Inner Kagoshima Bay in 1917.* All along the coast of Sakura-jima, except at the N.W. portion, there are promontories of various dimensions formed by lava streams; these latter having caused a certain modification in the contour in the immediate vicinity and sometimes leading to the formation of small lava islets off the coast. Marked elevations and depressions of the sea bottom were, however, confined almost entirely to the northern portion of the bay, these changes having accompanied a great volcanic outburst on more than one occasions previous to 1914. Fig. 9, which has been drawn from the new Navy charts of the Kagoshima bay and of the Kagoshima harbour, gives a general representation of the present depth of the sea around Sakura-jima. It will be noted that in the northern portion of the bay which is deep and in which the 50-and 70-fathom isobath lines run quite close to the coast, there exist three depth centres A, B, and C, respectively of the maximum depths of 85, 113, and 79

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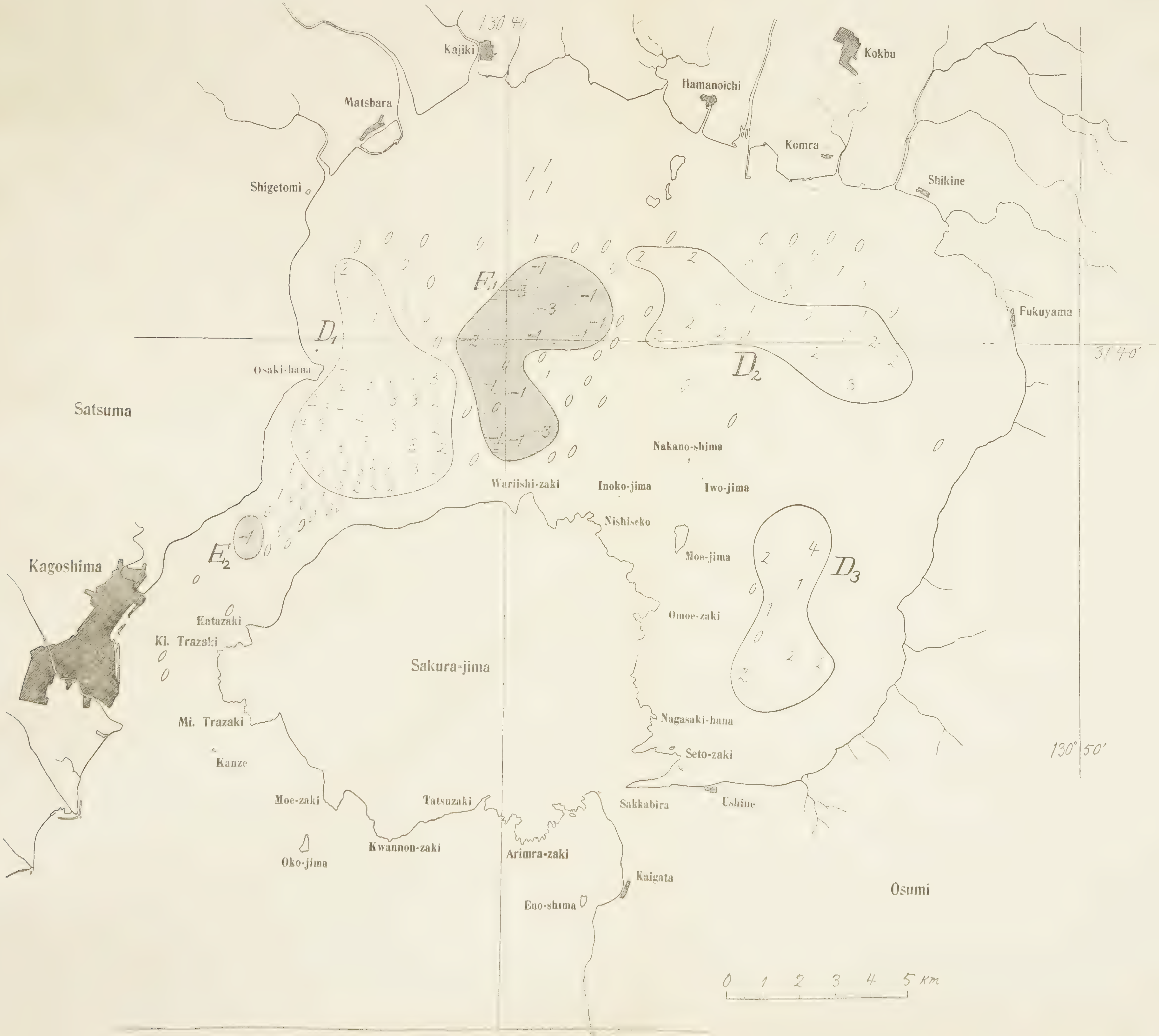
Fig. 9.

Chart of the Inner Kagoshima Bay, showing Changes in the Depth before and after the Sakura-jima Eruption of 1914. (Based on the comparison of the sounding in 1896 and those in 1916)

D_1, D_2, D_3,....Portions of the bay where the bottom was depressed more than 1 fathom.

E_1, E_2,.......Elevated portions of the bay bottom.

The figures indicate the amount of change of the water depth, in fathoms, plus (+) when augmented, and minus (−) when lessened.



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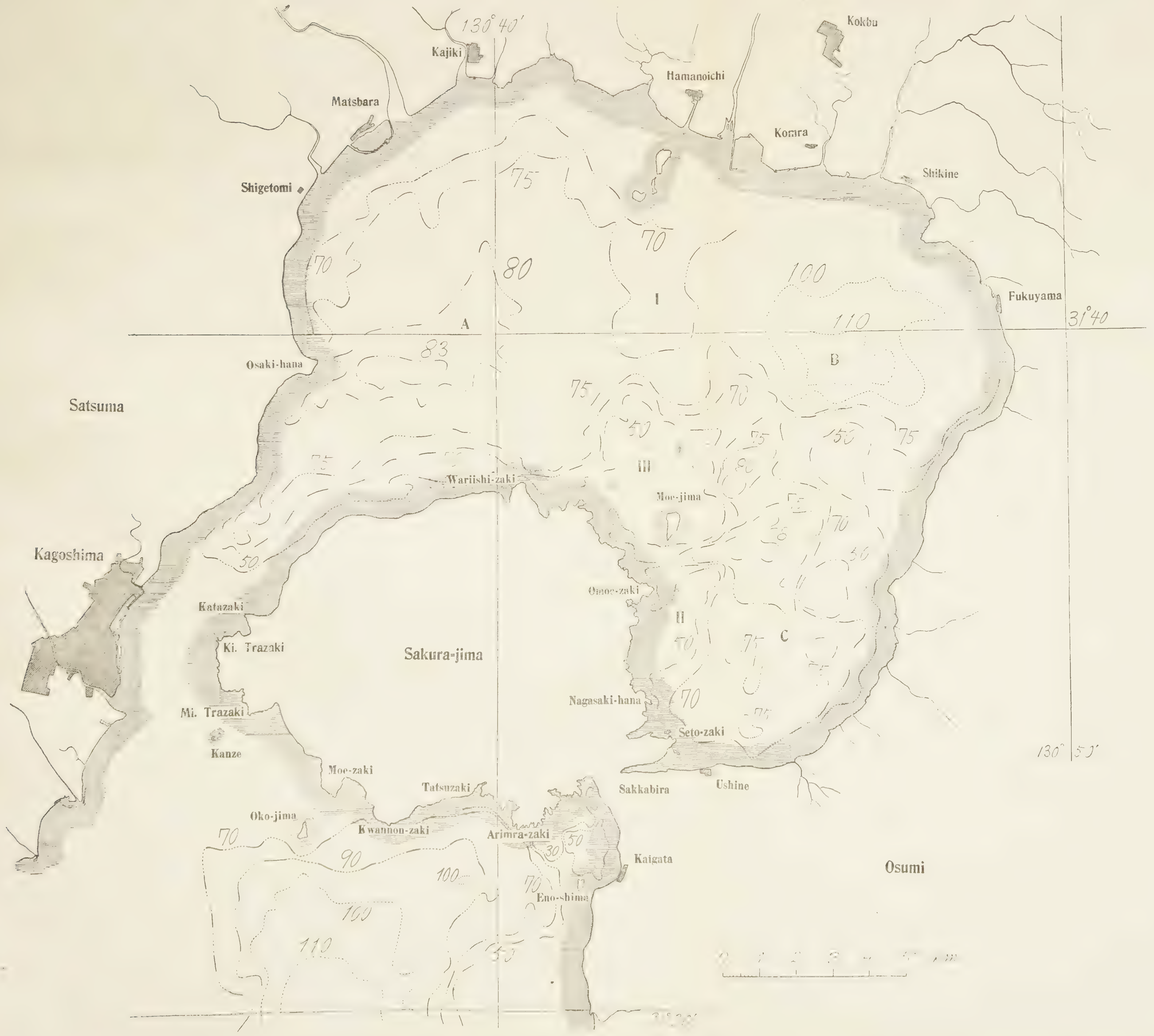


Fig. 10. Isobathymetric Chart of the Inner Kagoshima Bay after the Sakura-jima Eruption of 1914.

(Based on the hydrographic survey of the Imperial Navy in 1916.)

The depth is indicated in fathoms.

A, B, C ....Deepest Portions of the Inner Bay.

I, II, III....Shallow Portions „ „

fathoms; the first being situated at the west and the other two at the eastern parts of the sea under question. (B) and (C) form evidently a continuous trough, which is separated from (A) on the west by a sort of a N.-S. submarine ridge formed by the three areas I, II, and III, which are shallower than the adjacent parts, and which are bounded by the isobaths of 70; 50; and 50 fathoms respectively. From the figure, it will be observed that these areas form protuberances, the first from the northern shore of the bay and the two latter from the N.E. part of Sakura-jima, close along which the 50-fathom isobath runs otherwise continuous and parallel to the coast. In fact the formation of the area III is due to the great Sakura-jima eruption of 1779, when the sea bottom, previously 80 or 90 fathoms in depth, was raised up, forming amongst the others new islet of Moe-jima, whose present hight is 43.2 m. above the sea surface. It is probable that the area II was raised at the time of the eruption of the Bummei period, 1468–1476, when the lava promontory of Omoe-zaki was formed in the vicinity; also that the area I was raised in the Tempyo-Hoji period, 764 A.D., when the submarine eruption off the north coast of the bay resulted in the formation of three new islets, the Heta-kojima and the Oko-jima group of the present day. The ridge I-III-II thus seems to be mainly the effects of the elevation due to the eruptions during the historical times, and is to be regarded as the result of the powerful upward tension, or expansive force existing along the chain connecting the two active volcanoes of Sakura jima and Kirishima-yama. It is conceivable that with the formation of a new elevation area, the three depth centres A, B, and C, were affected and more or less deepened on the occasions of the different great eruptions of Sakura-jima, as was actually the case with the changes caused by the recent outburst.

14. *Difference in depth of Inner Kagoshima Bay before and after the eruption.* Pl. X in No. 2 of the Bulletin, Vol. VIII, gives a general sketch of the the contour of the bay bottom previous to the eruption of 1914, based on the hydrographic survey in 1896. In that year the maximum water depths in the northern inner bay were 83, 110, and 78 fathoms respectively at the areas A, B, and C (fig. 9), while the corresponding depths after the eruption have become 85, 113, and 84 fathoms. Hence we may say that the greatest depth of the bay was increased by 3 fathoms.

The amount of change in the water depth at different points of the bay before and after the great Sakura-jima outburst was from −3 fathoms (decrease) to +4 fathoms (increase); the pronounced variation being, as shown in fig. 10, principally localized at the three depression areas D_1, D_2, D_3, and the two elevation areas E_1 and E_2. The integral extension of the two latter is much smaller than that of the three former.

Change. (Ground level)	Water Depth.	Area.	Approximate Extension. (sq. km.)	Amount of Change. (fathoms.)	
				Average.	Maximum.
Depression.	Increase.	D_1	17.6	+2.4	+4
		D_2	15.0	+1.7	+3
		D_3	8.1	+1.8	+4
Elevation.	Decrease.	E_1	10.0	−1.3	−3
		E_2	0.8	−1	−1

Of the three depression areas D_1, D_2, and D_3, which approximately coincide with the three depth centres A, B, and C (fig. 9) respectively, the first shows the change most markedly, the increase in the water depth reaching 3 to 4 fathoms. This accounts for the specially great amount of the level changes at the Osaki-hana bench marks, situated nearest to the area D_1. In the two areas D_2 and D_3 the amount of the depression was a little smaller than in D_1.

Of the two elevation areas, E_1 is well defined and indicates the depth decrease of 1 to 3 fathoms. It is situated between the two depression areas D_1 and D_2, the centre being some 5 km. to the east of the Osaki-hana promontory. The small elevation area E_2 is situated to the S.W. of the depression area D_1 at the place where the inner bay joins the shallow Kagoshima strait.

The existence of the elevation areas E_1 and E_2 is by no means abnormal. On the contrary, their formation is quite similar to the elevation of the tract (III in fig. 9) about the Anei new islets at the time of the Anei (1779) eruption. From the proximity to the submarine ridge I III II (fig. 9) the principal elevation area E_1 may be supposed to have been brought into its present condition by the underground tension along the Sakura-jima and Kirishima-yama volcanic chain. It is hereby to be remembered that, with respect to the eruption of 1914, the three areas D_1, D_2, and D_3, are merely the maximum depression centres, the whole bottom of the inner bay having, with the exception of the two small elevated portions E_1 and E_2, been depressed more or less markedly. As shown in § 3, the disturbed region under and about the inner bay has, since 1915, undergone a slight elevation, and the centre of the 100 mm. upheaval line (fig. 2), which may be termed the origin of recovery, approximately coincides with the middle portion of the area E_1, at about $\varphi=31°40'$ N., $\lambda=130°40'$ E.

15. ***Depression volume.*** The depression volume at D_1, D_2, and D_3, is 0.149 c. km., while the elevation volume at E_1 and E_2 is about 0.025 c. km.; the resultant volume change at these five districts taken together being 0.124 c. km. of depression. In this connection it may be noted that the maximum level depressions along the W. coast of the inner bay was indicated at the B.M. No. 2474, and along the N. coast at the B.M. No. 2483. The amount of the change at these two places in 1915 referred to 1892 were 0.949 and 0.739 m., or when referred to the epoch immediately preceding the great Sakura-jima eruption in 1914, respectively 1.10 and 0.89 m. (See p. 156.) Thus the average depression for the bottom of the inner bay, with the exception of the 5 local area D_1, D_2, D_3, E_1, and E_2, may be assumed without the risk of exaggeration to be about 1 metre. This gives the depression volume of 0.271 c. km. Further, for the region around the inner bay, the depression volume is about 0.6 c. km. (See p. 160.) Hence the total volume of the resultant depression of the ground caused by the great eruption of 1914 comes out to be approximately 1.0 c.km., which agrees with the figure previously inferred (p. 161). In round numbers this is equal to half of the volume of the lava and ashes ejected from the volcano during the outbursts in question, and the ratio is not likely to be increased in the course of time, as the restitution of the disturbed region has already set in to a marked degree (Chapter I). On the other hand, the central part of the Sakura-jima island (now converted to a peninsula) indicates a trace of some permanent elevation (p. 168). The result is that in the eruption of 1914, the Sakura-jima has given out more material than has been compensated by the subsequent depression of the earth's crust under and about the mountain, which is consequently caused to become rarer in density. This accounts for the diminution of the force of gravity generally observed in the neighbourhood of a volcano.

16. ***On the origin of Inner Kagoshima Bay.*** We have seen that the bottom of the inner bay has with the exception of limited localities generally suffered a depression. A part of the depression has already been restituted; the ratio being, for the Osaki-hana promontory nearest to the depression centre, equal to 0.178/1.1 m. or 1/6 nearly. But it seems not likely that the entire depression should finally be cancelled. Each great eruption of Sakura-jima probably did produce a certain permanent deepening of the inner bay. In the eruption of 1914, the volume of the materials thrown out was 2.2 c. km., or nearly 1/12th of the whole mountain above the sea-level; the maximum amount of the bay bottom depression being about 4 fathoms. If the first stage in the building up of the Sakura-jima volcano consisted in submarine eruptions, the total volume of the lava brought out of the underground reservoir in the course of the subsequent time interval must be much greater than the mountain volume above stated, and we may imagine the consequent total depression of the inner bay to amount to 100 fathoms or so. In other words, the formation of the inner bay may be supposed to have been principally due to the building up of the Sakura-jima, and also of the Kirishima-yama, between which two volcanoes it is situated. The former Seto strait between the S.E. end of the "island" and the main land of the province of Osumi has already been blocked up dy the lava streams of 1914. Again, between the west end of the Sakura-jima and the province of Satsuma the water is quite shallow, with the minimum depth of only 20 fathoms at the strait centre, while the recent lava streams have narrowed the channel materially. A future lava outflow from the west flank of the volcano or an upheaval of the sea bottom may easily close up the Kagoshima channel, and reduce the present inner bay into a lake behind the Sakura-jima volcano.

17. *On the local limit of depression.* [*] The question of the future transformation of the inner Kagoshima bay naturally leads to the consideration of the depth of a large water body existing behind a volcano or between two volcanoes. Two very interesting examples of this type of geographical configuration are found in the volcanic regions of the Usu-san and the Tarumai-dake in the S.W. part of Hokkaido. The lake of Toya, 8 km. in diameter, is situated at the back of the Usu-san, or rather between the latter and the Makkarinopli (Yezo-Fuji); and the lake of Shikots, 8×4 km. in size, between the Tarumai-dake and the Eniwa-dake, at the distance of 42 km. to the N.E. of the first mentioned lake. These two lakes as well as the large Volcano Bay itself, which derives its name from the existence of the remarkable volcanoes of the Usu-san, the Makkarinopli, and the Komaga-take along its coast, were probably formed by the depression due to the building up of the different volcanoes in the respective vicinity. The maximum water depth of the Volcano Bay, about 50 km. in diameter, is 59 fathoms, or 107 m.; while that of the neighbouring lake of Toya, whose surface is 85 m. above the sea-level, is 106 fathoms (=192 m.), so that the bottom is also 107 m. below the latter. Again, the maximum depth of the lake of Shikots, whose surface is 248 m. above the sea-level, is 197 fathoms (=358 m.). The bottom which is flat, is therefore 110 m. below the sea-level. Thus it will be seen that the bottoms of the Volcano Bay and of the two lakes of Toya and Shikots, are all nearly at one and the same level, namely, obout 110 m. below the sea-level. This probably indicates, for the region concerned, the limit of the possible crustal subsidence, by which agency the three water bodies in question were brought into existence. It may be assumed that each volcanic district has a proper limit of the depression determined by its isostatic condition.

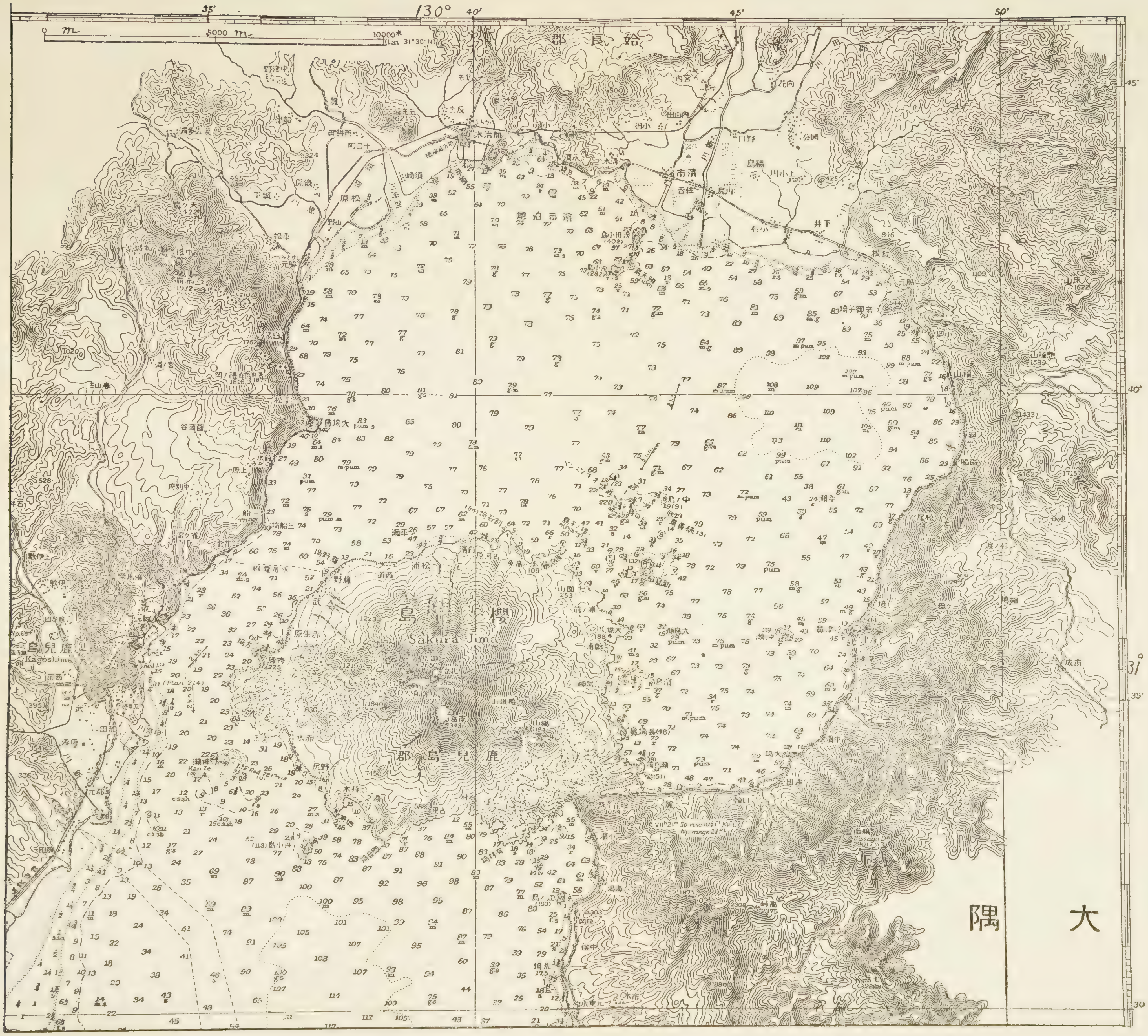
---

[*] This § is the translation of my article on the subject published in the *Toyo Gakugei Zasshi*, 1917.

In the case of the Kagoshima bay, the maximum water depth of the northern or inner portion, the "lake," is 113 fathoms, and is not much different from that of the main, or southern, portion, namely, 129 fathoms. The equality of the depth will become more complete in future, as the inner bay will be depressed more or less at the occurrence of new strong outbursts of the Sakura-jima.

Fig. 11. Chart of the Inner Kagoshima-Bay after the Sakura-jima Eruption of 1914.

Reproduced from the Imperial Navy Hydrographic Chart No 221 (new edition), compiled from the surveys in 1916.

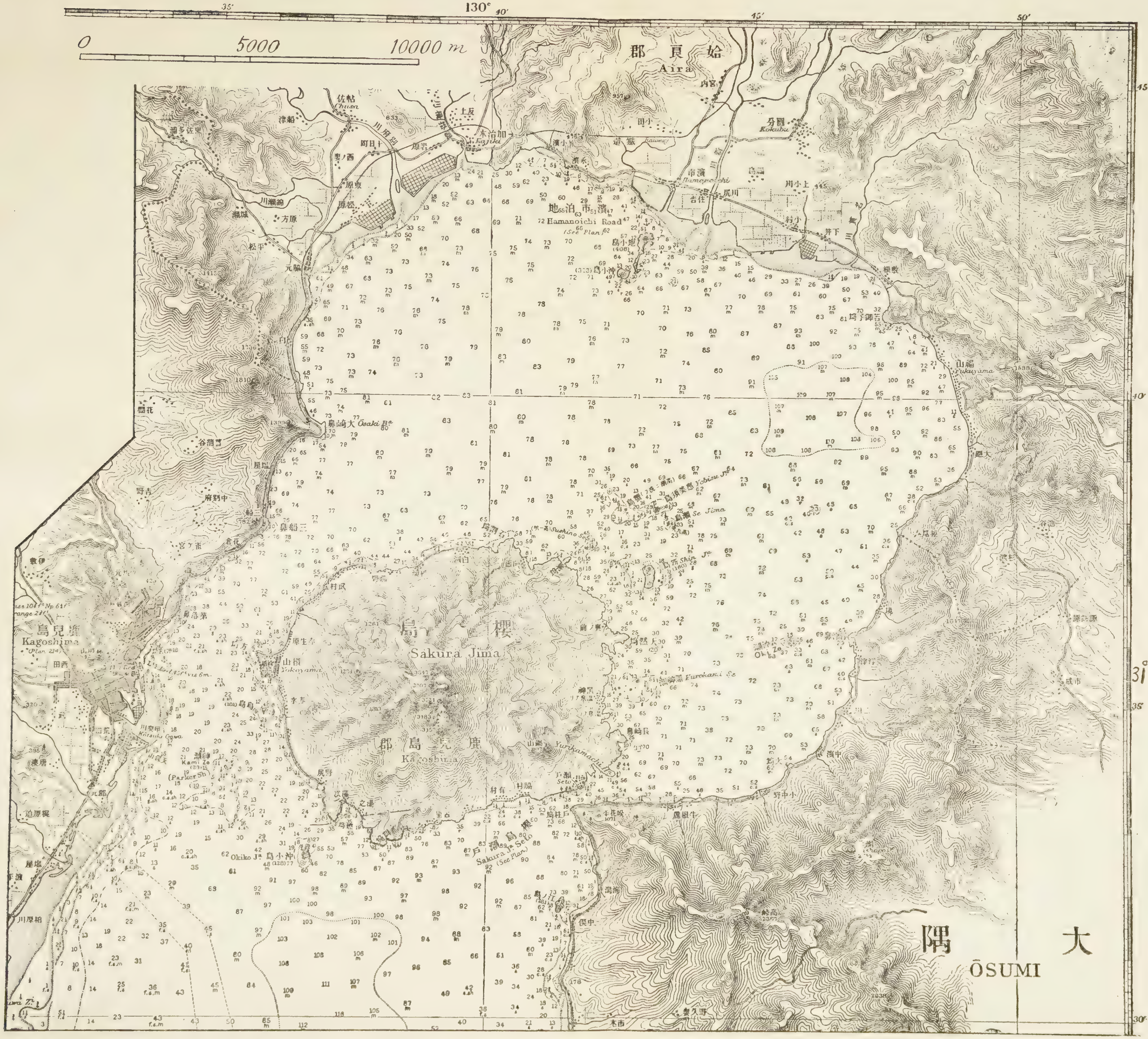


Soundings in Fathoms. (Height is expressed in feet above H. W. Springs.)

PL. LXXV.

Fig. 12. Chart of the Inner Kagoshima Bay before the Sakura-jima Eruption of 1914.

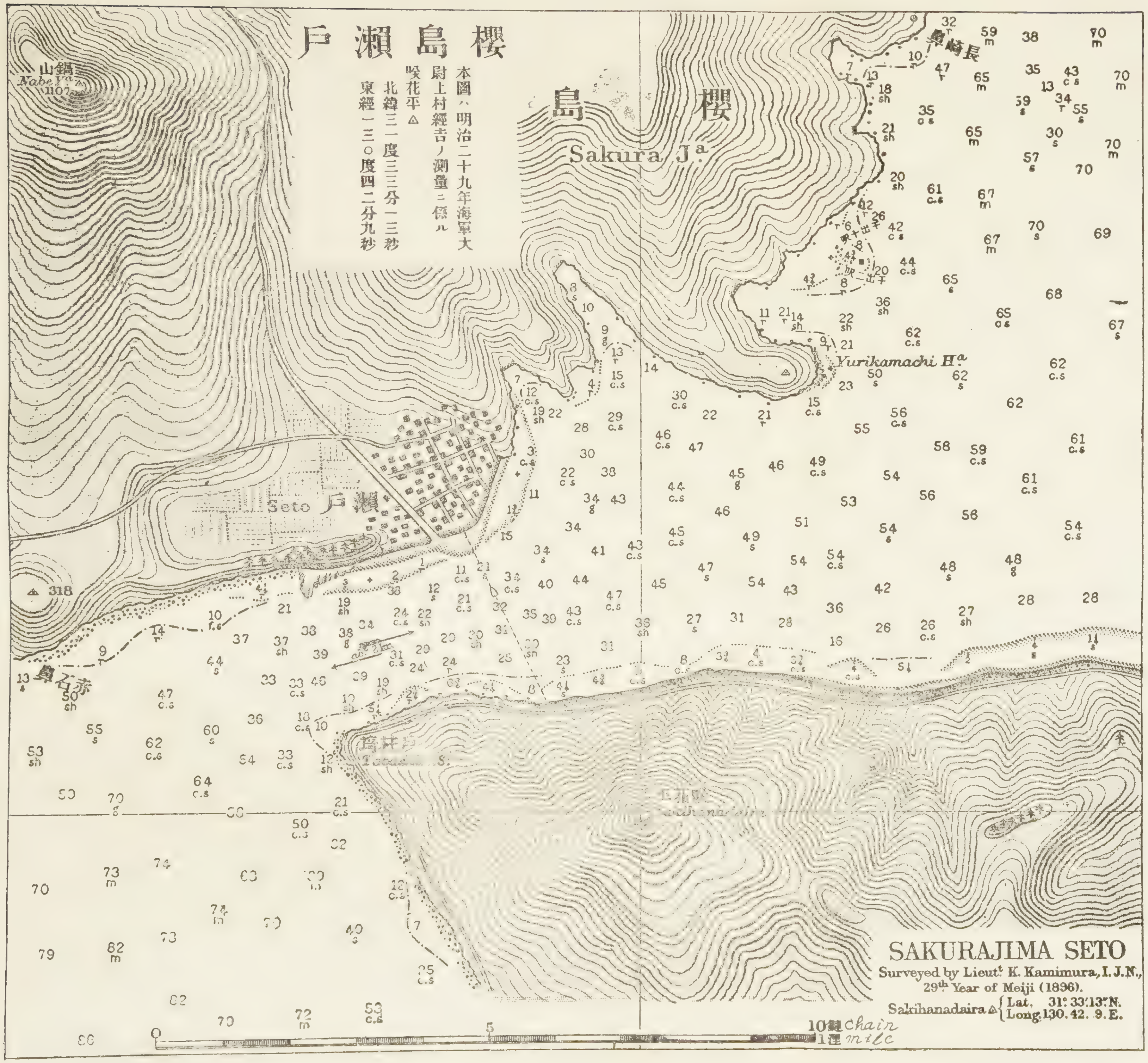
Reproduced from the Imperial Navy Hydrographic Chart No. 221 (old edition), compiled from the surveys in 1896.



Soundings in Fathoms. (Height is expressed in feet above H.W. Springs.)

鍋山
Nabe Ya.
1107
318
9
赤石鼻
13
s
50
sh
55
s
53
sh
59
70
g
70
73
m
79
82
m
86

Fig. 13. Chart of the Seto Strait (blocked up in 1914) surveyed in 1896.


櫻島瀬戸
本圖ハ明治二十九年海軍大尉上村經吉ノ測量ニ係ル
咲花平△
北緯三一度三三分一三秒
東經一三〇度四二分九秒
鍋山 Nabe Y^a. 1107
櫻島 Sakura J^a.
Seto 瀬戸
長崎鼻
Yurikamachi H^a.
赤石鼻
318
SAKURAJIMA SETO
Surveyed by Lieut^t. K. Kamimura, I. J. N.,
29th Year of Meiji (1896).
Sakihanadaira △ Lat. 31° 33′ 13″ N. Long. 130. 42. 9. E.
0
5
10鎖 chain
1浬 mile

Soundings in Fathoms. (Height is expressed in feet above H. W. Springs.)

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震災豫防調查會紀要

第八卷　第五號

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IMPERIAL EARTHQUAKE INVESTIGATION COMMITTEE.

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THE SAKURA-JIMA ERUPTIONS AND EARTHQUAKES. V.

Seismographical Observations of the Fore-shocks, After-shocks, and After-outbursts of the Great Sakura-jima Eruption of 1914.

By

F. Omori, Sc. D.,

Member of the Imperial Earthquake Investigation Committee.

With Plates LXXVII–LXXXVII.

CHAPTER I. OBSERVATION OF THE FORE-SHOCKS AT THE KAGOSHIMA METEOROLOGICAL OBSERVATORY.

1. ***Gray-Milne seismograph observation at Kagoshima.*** The Gray-Milne seismograph observation made on Jan. 11th and 12th, 1914, at the meteorological observatory of Kagoshima* forms a valuable contribution to the knowledge of the fore-shocks of the great Sakura-jima eruption which began on the 12th, at 10 A.M. The instrument, at rest in ordinary times, registered only those shocks which were intense enough to affect the electric contact-maker and thereby start the recording-drum into motion; the pointer magnification being 5 for the E.W. and the N.S. components and 10 for the vertical component. As will be seen from the list in Table I, the fore-shocks observed at Kagoshima numbered 418 in the course of the first 30⅓ hours between 3.41.20 A.M., on the 11th,

---

* See the Bulletin, Vol. VIII, No. 1.

TABLE I. HOURLY FREQUENCY OF THE EARTHQUAKES OBSERVED AT KAGOSHIMA ON JAN. 11TH AND 12TH, 1914, CLASSIFIED ACCORDING TO THE INTENSITY OF MOTION.

Day.	11th.						12th.					
Intensity. / Hour.	Unfelt.	Sensible.					Unfelt.	Sensible.				
		Slight.	Moderate.	Strong.	Violent.	Sum.		Slight.	Moderate.	Strong.	Violent.	Sum.
0–1 A.M.							4	16	1	—	—	17
1–2							2	7	—	—	—	7
2–3							3	4	—	—	—	4
3–4	2	1	—	—	—	1	14	12	1	—	—	13
4–5	5	1	2	—	—	3	5	6	2	—	—	8
5–6	2	2	1	—	—	3	8	11	1	—	—	12
6–7	—	—	—	—	—	—	3	15	3	—	—	18
7–8	1	1	—	—	—	1	1	11	1	—	—	12
8–9	5	2	—	—	—	2	12	12	1	—	—	13
9–10	3	1	—	1	—	2	17	7	—	—	—	7
10–11	3	—	—	—	—	—	13	4	—	—	—	4
11–12	4	5	1	—	—	6	7	4	—	—	—	4
0–1 P.M.	6	1	1	1	—	3	5	1	—	—	—	1
1–2	10	1	1	—	—	2	3	—	—	—	—	—
2–3	8	5	1	—	—	6	5	—	—	—	—	—
3–4	10	3	1	—	—	4	2	—	—	—	—	—
4–5	14	1	1	—	—	2	2	—	—	—	—	—
5–6	10	4	1	—	—	5	2	—	—	—	—	—
6–7	3	5	2	—	—	7	—	—	—	—	1	1
7–8	4	3	5	—	—	8						
8–9	15	10	3	—	—	13						
9–10	5	10	4	—	—	14						
10–11	12	11	3	—	—	14						
11–12	5	15	—	—	—	15						
Sum.	127	82	27	2	—	111	108	110	10	—	1	121

and 10 A.M., on the 12th. Thereafter, with the commencement of the eruption, the frequency rapidly decreased, but the disturbances continued to occur more or less for the several subsequent days. In Table II the list extends to the 18th of January (1914), bringing the seismic number up to 505. Had a tromometer been in use in Kagoshima at the commencement of the eruption, the earthquakes registered, both sensible and unfelt, would of course have been considerably more numerous.

The Kagoshima meteorological observatory stood on the top of a flat hill, 120 m. above sea-level, outside the northern end of the city, at $\varphi=31° 36' N.$, $\lambda=130° 33' E.$* Its site was at the distance of 10.4 km. from the centre of the Minami-dake crater in Sakura-jima, and was nearly in the accurate prolongation of the N. 73° W.–S. 73° E. eruption zone connecting the series of the craterlets on the S.E. and the W. flanks of the mountain. I give next a few remarks on the time relation of the fore-shocks.

2. *Frequency distribution of the fore-shocks.* According to Table I, the intensity distribution of the 467 shocks observed between 3 A.M., on the 11th, and 7 P.M., on the 12th, was as follows:—

	Earthquake Intensity.	Number of Earthquakes.
(i)	Unfelt,	235
(ii)	Slight,	192
(iii)	Moderate,	37
(iv)	Strong,	2
(v)	Violent (semi-destructive),	1

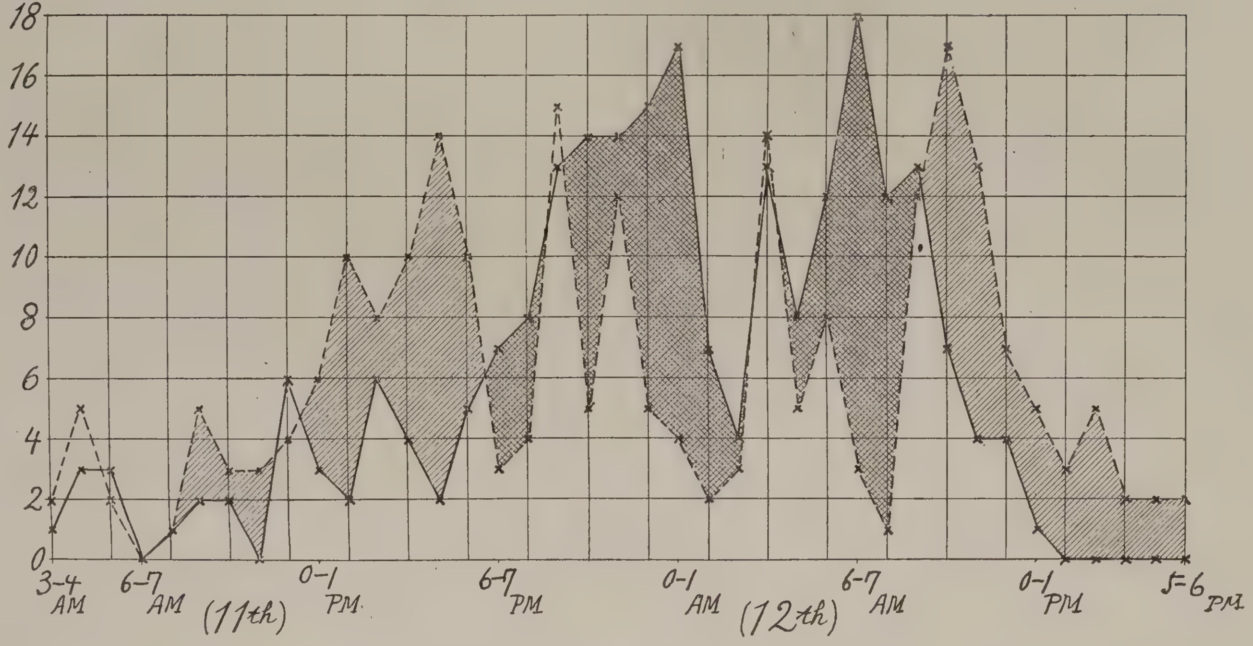
Thus the frequency of the (i) unfelt earthquakes was exactly 50% and those of the sensible (ii) slight and (iii) moderate shocks respectively 41 and 8% of the total number. The (iii) moderate earthquakes attained the maximum frequency between 6 and 11 P.M., on the 11th; while the two strong earthquakes took place between 9 and 10 A.M., and between 0 and 1 P.M., on the 11th. In other words, the (iii) and (iv) shocks occurred or were most numerous respectively about 24 and 12 hours before the first commencement of the eruption at 10 A.M., on the 12th.

---

* Removed in 1915 to its present position on the low suburb ground to the south of the city, at $\varphi=31° 34' N.$, $\lambda=130° 33' E.$

As will seen from fig. 1, the course of the time variation of the frequency of the unfelt earthquakes was different in several points from that of the sensible on s. Amongst the others, during the 1st 15 hours, i.e., from 3 A.M. till 6 P.M., on the 11th, the hourly number of the unfelt earthquakes remained on the whole greater than that of the others, in the ratio of 83 to 40, or nearly 2 : 1; while, during the next 15 hours, between 6 P.M., on the 11th, and 9 A.M., on the 12th, the sensible earthquakes became more numerous than the unfelt, in the ratio of 175 : 96, or nearly 2 : 1. This latter phenomenon, or the frequency preponderance of the stronger earthquakes over the smaller ones, is highly peculiar, and probably implies the intensification of the individual seismic movements in the hours immediately preceding the eruption, a supposition which is in accordance with the nature of the volcanic disturbances consisting of an abundant emission of smokes and ashes and an outflow of lava. From about 9 or 10 A.M., on the 12th, at the time of commencement of the outbursts, the unfelt earth quakes- became again more numerous than the sensible ones, both sorts of the shakings quickly decreasing till the time of occurrence of the violent shock at 6½ P.M. on the same day. Again, none of the premonitory earthquakes, which may be supposed to have been brought practically to end at about 3 or 4 P.M., on the 12th, was destructive or semi-destructive, and their maximum E.W. component motion (2a) was, according to the tromometer record in

Fig. 1. Hourly Frequency Variation of the Sakura-jima Fore-shocks instrumentally registered at the Kagoshima Meteorological Observatory.



▨.... Unfelt. ▩.... Sensible.

Dotted line relates to the unfelt earthquakes.

Full line „ „ sensible „

Tokyo, less than 0.03 mm., being considerably smaller than the corresponding maximum motion (=2.9 mm.) of the strong shock above referred to. This shows that the latter was of a great magnitude altogether different from the numerous precursory shakings of the volcanic outbursts. These two facts relating to the time of occurrence and the magnitude of the strong shock in the evening of the 12th seem to indicate that it was in nature a large earthquake and not local to the Sakura-jima only.

3. *3-hourly frequency of the fore-shocks.* The 3-hourly frequency of the premonitory earthquakes was as follows :—

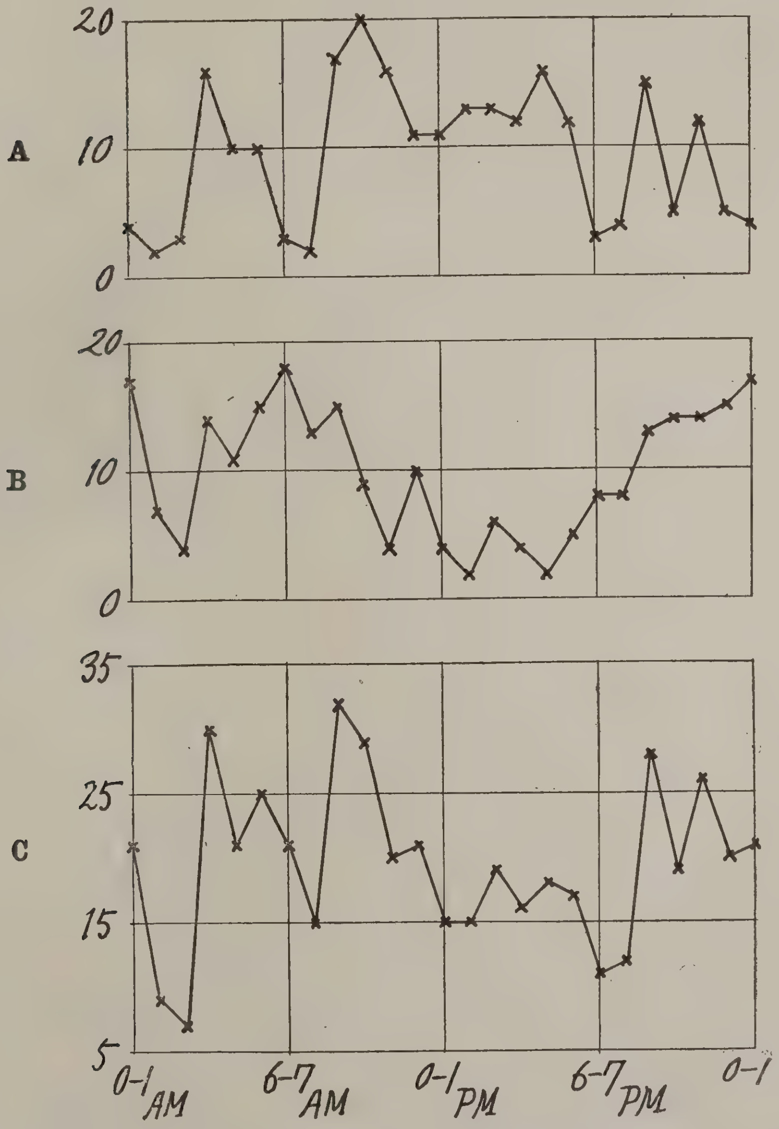
Hour.	11th.	12th.	Hour.	11th.	12th.
0–3 A.M.	0	37	0–3 P.M.	35	14
3–6	16	60	3–6	45	6
6–9	9	59	6–9	50	2
9–12	18	52	9–12	65	

It will be seen that the frequency increase during the 11th was in a nearly linear relation to the time, with the mean rate of about 3.0 shocks per hour.

In Table XIV of the Bulletin, Vol. VIII, No. 2, is given the hourly value of the barometric pressure at Kagoshima during the 5 days, from the 10th to the 14th of January, 1914. There is no apparent relation between the variation of the barometric pressure and that of the earthquake frequency.

4. *Diurnal variation.* From Table I and the illustration in fig. 2, it will be seen that the diurnal variation of the unfelt earthquakes indicates the minimum hourly frequency at 6–8 A.M. and 6–8 P.M., and also at 1–2 A.M. and 1–2 P.M., being rather opposite to that of the sensible shocks. The frequency variation of

Fig. 2. Diurnal Frequency Variation of the Sakura-jima Fore-shocks instrumentally registered at the Kagoshima Moteorological Observatory.



(A) Unfelt Earthquakes. (B) Sensible Earthquakes.
(C) Unfelt and Sensible Earthquakes taken together.

the unfelt and sensible earthquakes taken together shows 4 maxima more or less distinctly, at 8–9 A.M. and P.M., and at 3–4 A.M. and P.M. The diurnal frequency variation of the Sakura-jima foreshocks may thus be considered as having been maximum at the hours of the barometric maximum and minimum: a result similar to the relation found of the ordinary earthquakes in Tokyo, and of the *jinari* (earth sounds) at the hot spring place of Arima.

TABLE II. LIST OF THE VOLCANIC EARTHQUAKES REGISTERED WITH A GRAY-MILNE SEISMOGRAPH AT THE METEOROLOGICAL OBSERVATORY OF KAGOSHIMA. JAN., 11TH TO 18TH, 1914.

No.	Time of Occurrence.	Intensity.	Nature of motion *	No.	Time of Occurrence.	Intensity.	Nature of motion.*
	Jan. 11th, 1914.				**Jan. 11th 1914.**		
	h m s				h m s		
1	3 41 20 A.M.	0		14	5 07 40 A.M.	0	
2	43 00	0		15	27 45	1	Quick.
3	59 00	1	Quick.	16	58 00	2	Quick, with vert. motion; houses shaken.
4	4 01 40	2	Quick, with vert. vibrations.	17	7 45 44	1	Quick.
5	04 00	0		18	59 00	0	
6	06 20	0		19	8 01 00	0	
7	08 20	0		20	13 00	0	
8	15 15	1	Quick.	21	23 00	1	Quick.
9	26 40	2	Quick, with vert. vibrations; houses shaken.	22	29 00	0	
10	45 40	0		23	30 40	0	
11	54 00	0		24	39 00	0	
12	5 03 00	1	Quick.	25	56 00	1	Quick.
13	07 15	0		26	9 02 00	1	*Do.*

* The intensity of earthquake motion is distinguished as *unfelt, slight, rather moderate, moderate, rather strong, strong,* and *violent.* These seven degrees are denoted in this table respectively by the numerals 0, 1, 2, 3, 4, 5, and 6:—

0, Unfelt; 1, Slight; 2, Rather Moderate.: 3, Moderate; 4, Rather Strong; 5, Strong; 6, Violent.

No.	Time of Occurrence.	Intensity.	Nature of motion.
	Jan. 11th, 1914.		
27	$9^{h}\ 07^{m}\ 00^{s}$ A.M.	0	
28	21 00	0	
29	36 00	0	
30	57 45	5	Quick, with vert. motion; pendulumn clocks stopped.
31	10 37 30	0	
32	45 33	0	
33	58 00	0	
34	11 10 20	0	
35	12 30	1	Quick.
36	28 00	1	*Do.*
37	30 00	0	
38	32 00	1	Quick.
39	33 40	0	
40	38 25	1	Quick.
41	42 00	1	*Do.*
42	45 00	0	
43	46 54	2	Quick, with vert. motion; houses shaken.
44	0 05 00 P.M.	1	Quick.
45	09 30	0	
46	27 11	3	Strong vert. motion, with earth sound; ground cracked.
47	31 17	0	
48	34 00	0	
49	43 00	5	Quick, with vert. motion; pendulumn clocks stopped.
50	47 10	0	
51	50 00	0	
52	54 00	0	
53	1 04 35	0	
54	19 00	0	
55	23 49	0	
	Jan. 11th, 1914.		
56	$1^{h}\ 24^{m}\ 00^{s}$ P.M.	3	Quick, with vert. motion; houses shaken.
57	29 00	0	
58	41 30	0	
59	45 00	0	
60	46 20	0	
61	50 00	0	
62	51 25	1	Quick.
63	53 00	0	
64	54 00	0	
65	2 01 00	0	
66	02 30	0	
67	05 00	1	Quick.
68	07 30	0	
69	09 40	1	Quick.
70	15 00	0	
71	17 00	0	
72	23 00	1	Quick.
73	30 10	0	
74	34 17	1	Quick.
75	36 25	0	
76	45 23	1	Quick.
77	54 00	0	
78	54 59	2	Quick, with vert. vibration.
79	3 01 00	1	Quick.
80	09 20	0	
81	14 20	0	
82	15 50	0	
83	18 00	1	Quick.
84	30 40	0	

No.	Time of Occurrence.	Intensity.	Nature of motion.	No.	Time of Occurrence.	Intensity.	Nature of motion.
Jan. 11th, 1914.				**Jan. 11th, 1914.**			
85	3h 34m 00s P.M.	0		114	5h 20m 00s P.M.	0	
86	36 40	0		115	21 00	0	
87	39 00	0		116	24 00	3	Quick, with vert. motion; houses shaken.
88	46 34	0		117	27 00	0	
89	50 00	0		118	43 00	0	
90	51 30	1	Quick.	119	44 55	1	Quick.
91	52 10	2	Quick, with vert. motion; houses shaken.	120	50 00	0	
92	58 00	0		121	51 00	0	
93	4 01 20	0		122	58 00	1	Quick.
94	07 00	0		123	59 00	1	*Do.*
95	12 10	2	Quick, with vert. motion; houses shaken.	124	6 01 00	1	*Do.*
96	14 00	0		125	01 30	1	*Do.*
97	17 25	0		126	14 20	0	
98	20 00	0		127	15 40	0	
99	25 00	0		128	20 00	0	
100	27 00	0		129	22 00	1	Quick.
101	35 00	0		130	24 00	1	*Do.*
102	38 00	0		131	25 00	1	*Do.*
103	42 00	0		132	47 00	2	Quick, with vert. motion; houses shaken.
104	43 20	0		133	53 00	2	*Do.*
105	47 00	0		134	7 01 00	2	*Do.*
106	48 29	1	Quick.	135	10 00	1	Quick.
107	56 20	0		136	15 15	1	*Do.*
108	58 00	0		137	22 10	2	Quick, with vert. motion; houses shaken.
109	5 02 30	0		138	30 20	2	*Do.*
110	04 00	1	Quick.	139	34 00	0	
111	05 30	0		140	36 00	1	Quick.
112	11 30	0		141	42 00	2	Quick, with vert. motion; houses shaken.
113	15 30	0		142	47 00	0	

No.	Time of Occurrence.	Intensity.	Nature of motion.
	Jan. 11th, 1914.		
143	$7^{h}\ 51^{m}\ 00^{s}$ P.M.	3	Quick, with vert. motion; houses shaken.
144	53 00	0	
145	58 00	0	
146	8 00 00	1	Quick.
147	05 00	0	
148	08 00	0	
149	11 30	0	
150	12 00	2	Quick, with vert. motion; houses shaken.
151	13 00	1	Quick.
152	18 00	0	
153	19 00	0	
154	21 00	0	
155	23 00	2	Quick, with vert. motion; houses shaken.
156	26 50	1	Quick.
157	28 00	0	
158	32 00	0	
159	34 00	2	Quick, with vert. motion; houses shaken.
160	41 00	0	
161	43 00	0	
162	44 00	0	
163	44 30	0	
164	45 00	1	Quick.
165	46 00	1	*Do.*
166	48 00	0	
167	48 30	0	
168	49 00	1	Quick.
169	51 00	1	*Do.*
170	55 00	0	
171	56 00	1	Quick.
	Jan. 11th, 1914.		
172	$8^{h}\ 57^{m}\ 00^{s}$ P.M.	1	Quick.
173	58 00	1	*Do.*
174	9 00 00	2	Quick, with vert. motion; houses shaken.
175	07 00	1	Quick.
176	08 00	2	Quick, with vert. motion; houses shaken.
177	12 00	1	Quick.
178	18 00	0	
179	23 00	1	Quick.
180	28 00	1	*Do.*
181	30 00	1	*Do.*
182	33 00	0	
183	37 00	1	Quick.
184	38 00	0	
185	39 00	1	Quick.
186	44 00	0	
187	45 00	1	Quick.
188	46 00	1	*Do.*
189	48 00	0	
190	49 00	1	Quick.
191	52 00	2	Quick, with vert. motion; houses shaken.
192	59 00	2	*Do.*
193	10 00 00	2	*Do.*
194	01 00	0	
195	03 00	1	Quick.
196	04 00	1	*Do.*
197	07 00	1	*Do.*
198	11 00	1	*Do.*
199	13 00	0	
200	16 00	0	

No.	Time of Occurrence.	Inten-sity.	Nature of motion.
	Jan. 11th, 1914.		
201	$10^{h}\ 17^{m}\ 00^{s}$ P.M.	0	
202	19 00	1	Quick.
203	21 00	1	*Do.*
204	22 00	0	
205	24 00	2	Quick, with vert. motion; houses shaken.
206	27 00	0	
207	30 00	0	
208	31 00	1	Quick.
209	35 00	1	*Do.*
210	38 00	1	*Do.*
211	39 00	1	*Do.*
212	44 00	0	
213	45 00	0	
214	47 00	0	
215	49 00	0	
216	50 00	0	
217	51 00	1	Quick.
218	58 00	3	Quick, with vert. motion; houses shaken.
219	11 03 00	1	Quick.
220	09 00	1	*Do.*
221	11 00	0	
222	14 00	1	Quick.
223	15 00	1	*Do.*
224	17 00	0	
225	19 00	1	Quick.
226	20 00	1	*Do.*
227	20 30	1	*Do.*
228	23 00	0	
229	24 30	1	Quick.
	Jan. 11th, 1914.		
230	$11^{h}\ 28^{m}\ 00^{s}$ P.M.	0	
231	29 00	1	Quick.
232	30 00	1	*Do.*
233	34 00	0	
234	35 00	1	Quick.
235	37 00	1	*Do.*
236	51 00	1	*Do.*
237	53 00	1	*Do.*
238	58 00	1	*Do.*
	Jan. 12th, 1914.		
239	0 03 00 A.M.	1	Quick.
240	04 00	1	*Do.*
241	05 00	0	
242	06 00	1	Quick.
243	09 00	1	*Do.*
244	14 00	0	
245	18 00	1	Quick.
246	22 00	1	*Do.*
247	24 00	1	*Do.*
248	25 00	1	*Do.*
249	32 00	1	*Do.*
250	33 00	1	*Do.*
251	34 00	0	
252	35 00	1	Quick.
253	40 00	3	Quick, with vert. motion; houses shaken.
254	41 00	1	Quick.
255	51 00	1	*Do.*
256	52 00	1	*Do.*

No.	Time of Occurrence.	Intensity.	Nature of motion.
	Jan. 12th, 1914.		
	h m s		
257	0 54 00 A.M.	0	
258	55 00	1	Quick.
259	57 00	1	*Do.*
260	1 00 00	0	
261	06 00	0	
262	08 00	1	Quick.
263	20 00	1	*Do.*
264	26 00	1	*Do.*
265	31 00	1	*Do.*
266	43 00	1	*Do.*
267	51 00	1	*Do.*
268	54 00	1	*Do.*
269	2 05 00	1	*Do.*
270	09 00	1	*Do.*
271	20 00	0	
272	29 00	0	
273	41 00	1	Quick.
274	49 00	1	*Do.*
275	54 00	0	
276	3 04 00	1	Quick.
277	11 00	1	*Do.*
278	14 00	1	*Do.*
279	16 00	1	*Do.*
280	18 00	1	*Do.*
281	20 00	1	*Do.*
282	22 00	0	
283	23 00	1	Quick.
284	27 00	0	
285	3 29 00 A.M.	1	Quick.
286	32 00	0	
287	35 00	2	Quick, with vert. motion; houses shaken.
288	36 00	1	Quick.
289	38 00	1	*Do.*
290	40 00	0	
291	41 00	0	
292	43 00	1	Quick.
293	44 00	0	
294	46 00	0	
295	47 00	0	
296	48 00	0	
297	50 00	1	Quick.
298	54 00	0	
299	56 00	0	
300	57 00	0	
301	58 00	0	
302	59 00	0	
303	4 04 00	1	Quick.
304	06 00	0	
305	08 00	2	Quick, with vert. motion; houses shaken.
306	09 00	1	Quick.
307	10 00	0	
308	23 00	0	
309	30 00	1	Quick.
310	37 00	0	
311	42 00	0	
312	43 00	2	Quick, with vert. motion; houses shaken.

No.	Time of Occurrence.	Inten-sity.	Nature of motion.	No.	Time of Occurrence.	Inten-sity.	Nature of motion.
	Jan. 12th, 1914.				Jan. 12th, 1914.		
313	$4^h\ 46^m\ 00^s$ A.M.	1	Quick.	341	$6^h\ 15^m\ 30^s$ A.M.	2	Quick; houses shaken.
314	49 00	1	* *Do.*	342	25 00	1	Quick.
315	56 00	1	* *Do.*	343	26 00	1	*Do.*
316	5 05 00	1	* *Do.*	344	27 00	1	*Do.*
317	06 00	1	*Do.*	345	28 00	0	
318	07 00	0		346	32 00	2	Quick; houses shaken.
319	15 00	0		347	34 00	1	Quick.
320	16 00	1	Quick.	348	38 00	1	*Do.*
321	17 00	1	*Do.*	349	41 00	1	*Do.*
322	19 00	0		350	45 00	0	
323	21 00	0		351	47 00	0	
324	23 00	0		352	52 00	1	* Quick.
325	29 00	0		353	53 00	1	*Do.*
326	31 00	1	Quick.	354	55 00	1	*Do.*
327	33 00	1	*Do.*	355	57 00	1	*Do.*
328	35 00	1	*Do.*	356	59 00	1	*Do.*
329	38 00	0		357	7 03 00	1	*Do.*
330	41 00	1	Quick.	358	10 00	1	*Do.*
331	47 00	1	*Do.*	359	14 00	1	*Do.*
332	49 00	3	Quick, with vert motion; houses shaken.	360	17 00	1	* *Do.*
333	51 00	0		361	23 00	1	*Do.*
334	55 00	1	Quick.	362	25 00	1	*Do.*
335	57 00	1	*Do.*	363	32 00	1	*Do.*
336	6 01 00	1	*Do.*	364	33 00	0	
337	03 00	2	Slow; houses shaken.	365	34 00	1	* Quick.
338	06 00	1	Quick.	366	41 00	1	* Slow.
339	09 00	1	*Do.*	367	46 00	2	Quick; houses shaken.
340	11 00	1	*Do.*	368	47 00	1	* Quick.

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* Not instrumentally registered.

No.	Time of Occurrence	Intensity.	Nature of motion.
	Jan. 12th, 1914.		
	h m s		
369	7 49 00 A.M.	1	Quick.
370	8 05 00	1	*Do.*
371	06 00	0	
372	07 00	1	Quick.
373	09 00	1	*Do.*
374	14 00	1	*Do.*
375	16 00	0	
376	17 00	1	Quick.
377	19 00	0	
378	23 00	0	
379	25 00	1	Quick.
380	27 00	3	Quick; houses shaken.
381	29 00	1	Quick.
382	33 00	0	
383	35 00	0	
384	35 35	1	Quick.
385	38 00	1	*Do.*
386	39 00	1	*Do.*
387	41 00	1	*Do.*
388	44 00	0	
389	46 00	0	
390	47 00	0	
391	51 00	0	
392	54 00	0	
393	55 00	1	Quick.
394	58 00	0	
395	9 05 00	0	
396	07 00	0	
	Jan. 12th, 1914.		
	h m s		
397	9 08 00 A.M.	0	
398	10 00	0	
399	10 30	1	Quick.
400	12 00	0	
401	13 00	1	Quick.
402	16 00	0	
403	17 00	1	Quick.
404	20 00	0	
405	26 00	0	
406	27 30	1	Quick.
407	30 00	0	
408	32 00	0	
409	34 00	0	
410	35 00	0	
411	37 00	1	Quick.
412	44 00	0	
413	45 00	0	
414	48 00	0	
415	51 00	1	Quick.
416	53 00	1	*Do.*
417	55 00	0	
418	57 00	0	
419	10 01 00	0	
420	04 00	0	
421	06 00	0	
422	07 00	0	
423	14 00	1	Quick.
424	16 30	1	*Do.*

Jan. 12th, 1914.

No.	Time of Occurrence.	Intensity.	Nature of motion.
425	10 18 00 A.M.	0	
426	21 30	1	Quick.
427	23 00	0	
428	24 00	0	
429	32 00	0	
430	34 00	0	
431	44 30	0	
432	49 00	1	Quick.
433	53 00	0	
434	56 00	0	
435	58 00	0	
436	11 00 00	0	
437	02 00	1	Quick
438	13 35	1	*Do.*
439	15 00	0	
440	23 00	1	Quick.
441	27 00	1	*Do.*
442	32 00	0	
443	34 00	0	
444	38 00	0	
445	42 00	0	
446	43 00	0	
447	0 06 30 P.M.	1	Quick.
448	08 00	0	
449	17 00	0	
450	20 00	0	
451	34 00	0	
452	57 00	0	
453	1 06 00 P.M.	0	
454	14 00	0	
455	28 20	0	
456	2 18 30	0	
457	22 00	0	
458	33 00	0	
459	37 00	0	
460	43 00	0	
461	3 15 00	0	
462	40 00	0	
463	4 09 00	0	
464	28 00	0	
465	5 06 00	0	
466	46 00	0	
467	6 29 00	6	
468	8 11 00	1	* Quick.
469	9 13 00	1	* *Do.*

Jan. 13th, 1914.

No.	Time of Occurrence.	Intensity.	Nature of motion.
470	9 36 00 A.M.	1	* Quick.
471	4 09 00 P.M.	4	* Quick; houses shaken.
472	11 00	1	* Quick.
473	45 00	1	* *Do.*
474	11 45 00	1	* *Do.*

Jan. 14th, 1914.

No.	Time of Occurrence.	Intensity.	Nature of motion.
475	0 34 00 A.M.	1	* Quick.
476	2 10 00	1	* *Do.*

* Not instrumentally registered.

No.	Time of Occurrence.	Intensity.	Nature of motion.	No.	Time of Occurrence.	Intensity.	Nature of motion.
Jan. 15th, 1914.				Jan. 16th, 1914.			
477	h m s 1 42 00 P.M.	2	Quick; houses shaken.	493	h m s 0 37 00 P.M.	0	
478	6 30 00	0		494	2 27 00	1	Quick.
479	50 00	0		495	6 04 00	0	
480	7 05 00	1	Quick.	496	20 00	0	
481	44 00	0					
482	50 00	0		Jan. 17th, 1914.			
483	9 25 00	0		497	2 50 00 A.M.	1	Quick.
484	10 59 00	0		498	5 38 00	1	*Do.*
485	11 43 00	0		499	43 00	0	
Jan. 16th, 1914.				Jan. 18th, 1914.			
486	4 50 00 A.M.	0		500	5 31 00 A.M.	1	× Quick.
487	5 10 00	0		501	11 33 00	1	× *Do.*
488	11 00	0		502	1 10 00 P.M.	0	×
489	7 18 00	0		503	2 43 00	0	×
490	10 00 00	1	Quick.	504	3 11 00	0	×
491	11 57 00	0		505	6 57 00	2	× Quick; houses shaken.
492	0 15 00 P.M.	0					

× Registered by a horizontal pendulum tromometer.

5. ***Time difference between the successive earthquake occurrences.*** The 471 earthquakes registered at the Kagoshima meteorological observatory from Jan. 11th, 3.41.20 A.M. to the next day, 9.13.00 P.M., had the average interval of 5^m18^s. Of these, 404 occurred at successive time differences less than 5 minutes, the maximum frequency, about 46% in amount, corresponding to the interval of about 2 minutes. (See Table III.)

If we take the series of 2 or more earthquakes with time difference under 5 minutes as composing a group, and combine their average time of occurrence with those of single earthquakes, the maximum frequency corresponds to the intervals of 10 to 13 minutes. (See Tables IV and V.)

Comparison with the after-shocks of great tectonic earthquakes. For the sake of comparison I give in Tables III and V the relative frequency of the shocks corresponding to the different lengths of the successive interval for the cases of the after-shocks of the Mino-Owari, Nemro, and Akita earthquakes, as follows:—

Mino-Owari Eqke. of Oct. 28th, 1891, at 6.37 A.M.: 1258 after-shocks observed at the Gifu meteorological observatory between Oct. 29th and Nov. 10th, 1891.

Nemro Eqke. of March 22nd, 1894, at 7.56 P.M.: 276 after-shocks observed at the Nemro met. observatory between March 22nd (7.56.06 P.M.) and 25th (11.44.00 P.M.) 1894.

Riku-U Eqke. of Aug. 31st, 1896, at 5 P.M.: 88 after-shocks observed at the Akita met. observatory between Aug. 31st (5.51.54 P.M.) and Sept. 1st (2.53.42 P.M.), 1896.

The numbers of the shocks occurring at successive intervals less than 5 minutes were 681; 146; and 47 respectively for the Mino-Owari, Nemro, and Riku-U earthquakes; the maximum frequency at Gifu and Nemro, 31 to 49%, corresponding to the interval of about 2 minutes. The time interval in question must depend, of course, on the magnitude of the volcanic tension or seismic stress at the source of disturbance and the radial distance of the observing place from the latter. Still the quick successive occurrences of the volcanic earthquakes at Kagoshima and of the tectonic after-shocks at Gifu and Nemro, as will be seen from Table III and fig. 3, followed nearly similar courses, the frequency culminating in each case at the interval of about 2 min.,

TABLE III. PERCENTAGE AMOUNT OF THE NUMBER OF THE EARTHQUAKES OCCURRING AT DIFFERENT SUCCESSIVE INTERVALS.

Interval.	Kagoshima.	Gifu.	Nemro.	Akita.
m s m s 0.00—0.30	0.0%	0.4%	2.1%	—
0 30—1.30	12.5	18.7	14.9	—
1.30—2.30	47.7	30.6	49.0	—
2.30—3.30	17.1	24.3	19.1	—
3.30—4.30	10.2	14.1	8.5	—
4.30—5.30	12.5	11.9	6.4	—
Total number of cases.	88	235	47	14

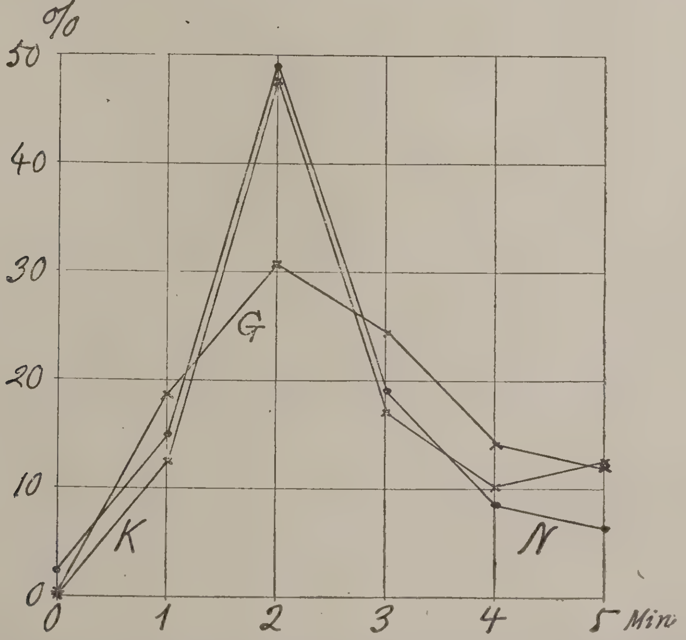

Fig. 3. Relative Frequency of the Different Values of the Time Interval between the Successive Earthquake Occurrences.

K....Kagoshima. G....Gifu. N....Nemuro.

The distances of the Kagoshima, Gifu, and Nemro meteorological observatories from the mean centers of disturbance concerned were respectively about 14 ; 10 ; and 120 km.

With respect to the interval over 5 minutes, the maximum frequency occurred between 8 min. and 13 min. both at Gifu and Nemro, being similar to the case at Kagoshima (Table V). Taking together the earthquakes at Kagoshima, Gifu, Nemro, and Akita, the frequency was greatest for the interval of 8 to 13 min., attaining the maximum at 10 and 11 min. Should a great number of small shocks occur simultaneously or within the time interval of $\frac{1}{2}$ min. or so from neighbouring points, the result would be a considerable earthquake. A great destructive shock is, however, not followed by such a disturbance, at least not in the same, or a closely lying district. Hence it is conceivable that volcanic earthquakes or after-shocks tend to occur most frequently at certain time intervals, dependent, amongst the others, on the imperfectly elastic condition of the upper part of the earth's crust.*

TABLE IV. SUCCESSIVE TIME DIFFERENCES OF THE EARTHQUAKES OR EARTHQUAKE GROUPS OBSERVED AT THE KAGOSHIMA METEOROLOGICAL OBSERVATORY ON JAN. 11TH AND 12TH, 1914.

(Earthquakes occurring at successive intervals under 5 minutes are treated as forming a single group.)

Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.	Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.
Jan. 11th			**Jan. 11th.**		
h m h m		m s	h m h m		m s
3 $40\frac{1}{3}$ — 3 43 A.M.	2		4 $45\frac{2}{3}$ A.M.	1	
		21 42			8 20
3 59 — 4 $8\frac{1}{3}$	5		4 54	1	
		11 23			12
4 $15\frac{1}{4}$	1		5 03 — 5 $7\frac{2}{3}$	3	
		11 5			21 45
4 $26\frac{2}{3}$	1		5 $27\frac{3}{4}$	1	
		19 20			30 15

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* The time intervals between the successive small eruptions of the Asama-yama have been considered in the Bulletin, Vol. VII.

Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.	Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.
Jan. 11th.			Jan. 11th.		
h m h m		m s	h m h m		m s
5 58 A.M.	1	107 44	3 01 P.M.	1	15 23
7 45$\frac{11}{15}$	1	14 16	3 09$\frac{1}{3}$— 3 18	4	20 42
7 59 — 8 01	2	13	3 30$\frac{2}{3}$— 3 39	4	14 59
8 13	1	10	3 46$\frac{6}{10}$— 3 52$\frac{1}{6}$	4	24 35
8 23	1	6 50	3 58 — 4 27	9	27 38
8 29 — 8 30$\frac{2}{3}$	2	9 10	4 35 — 4 48$\frac{1}{2}$	6	28 38
8 39	1	22 40	4 56$\frac{1}{3}$— 5 27	11	36
8 56 — 9 07	1	20 40	5 43 — 5 51	4	12 39
9 21	1	15	5 58 — 6 1$\frac{1}{2}$	4	20 17
9 36	1	21	6 14$\frac{1}{3}$— 6 25	6	26 50
9 57	1	40 30	6 47	1	6
10 37$\frac{1}{2}$	1	8 8	6 53	1	8
10 45$\frac{2}{3}$	1	13 38	7 1	1	9
10 58	1	13 25	7 10	1	5 15
11 10$\frac{1}{3}$—12 30	2	25 35	7 15$\frac{1}{4}$	1	6 55
11 28 —11 46$\frac{9}{10}$	8	30 15	7 22$\frac{1}{6}$	1	11 17
0 5 — 0 9$\frac{1}{2}$P.M.	2	23 28	7 30$\frac{1}{3}$— 7 36	3	8 33
0 27$\frac{1}{6}$— 0 34	3	17 50	7 42	1	5
0 43 — 0 54	4	16 02	7 47	1	5
1 4$\frac{7}{12}$	1	19 22	7 51 — 7 53	2	7
1 19 — 1 29	4	24 48	7 58 — 8 00	2	14 54
1 41$\frac{1}{2}$— 1 54	7	16 35	8 5 — 8 13	5	11 20
2 01 — 2 09	5	10 40	8 18 — 8 34	8	18 46
2 15 — 2 17	2	7	8 41 — 8 51	10	12 48
2 23	1	10 37	8 55 — 9 00	5	10 18
2 30$\frac{1}{6}$— 2 36$\frac{5}{12}$	3	11 51	9 7 — 9 8	2	4 30
2 45$\frac{7}{15}$	1	8 57	9 12	1	6
2 51 — 2 54$\frac{5}{6}$	2	6 35	9 18	1	5

Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.	Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.
Jan. 11th.			Jan. 12th.		
h m h m		m s	h m h m		m s
9 23 P.M.	1		2 41 A.M.	1	
		11 10			8
9 28 — 9 39	6		2 49	1	
		13 10			5
9 44 — 9 52	6		2 54	1	
		15			10
9 59 —10 07	6		3 04	1	
		9 40			
10 11 —10 13	2		3 11 — 4 10	31	
		14 35			
10 16 — 10 39	12		4 23	1	
		21 05			7
10 44 —10 51	6		4 30	1	
		10 20			7
10 58	1		4 37	1	
		5			8
11 03	1		4 42 — 4 49	4	
		19 49			11
11 09 —11 37	16		4 56	1	
		29 11			10
11 51 —11 53	2		5 05 — 5 07	3	
		6			12 50
11 58	1		5 15 — 5 23	6	
		7 24			15 01
Jan. 12th.			5 29 — 5 41	7	
					26 34
0 03 — 0 09 A.M.	5		5 47 — 6 15½	11	
		10 36			33 53
0 14 — 0 18	2		6 25 — 6 47	10	
		7 40			22 12
0 22 — 0 25	3		6 52 — 7 03	6	
		10 50			17 10
0 32 — 0 35	4		7 10 — 7 17	3	
		6			10 20
0 40 — 0 41	2		7 23 — 7 25	2	
		14 20			9
0 51 — 1 00	6		7 32 — 7 34	3	
		12 10			8
1 06 — 1 08	2		7 41	1	
		13			6 20
1 20	1		7 46 — 7 49	3	
		6			19 25
1 26	1		8 05 — 8 09	4	
		5			28 46
1 31	1		8 14 — 8 58	21	
		12			36 20
1 43	1		9 05 — 9 20	10	
		9 30			19 48
1 51 — 1 54	2		9 26 — 9 37	7	
		14 30			23 54
2 05 — 2 09	2		9 44 —10 07	11	
		13			24
2 20	1		10 14 —10 24	6	
		9			13 30
2 29	1		10 32 —10 34	2	
		12			11

Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.	Time of Earthquake Occurrence.	Number of Eqkes.	Successive Time Difference.
Jan. 12th.			Jan. 12th.		
h m h m 10 44 A.M.	1	m s 12 20	h m h m 2 33 — 2 37 P.M.	2	m s 8
10 49 —11 02	6	17 40	2 43	1	32
11 13 —11 15	2	11	3 15	1	25
11 23 —11 27	2	12 48	3 40	1	29
11 32 —11 43	5	29 12	4 09	1	19
0 06 — 0 08 P.M.	2	11 30	4 28	1	38
0 17 — 0 20	2	16 30	5 06	1	40
0 34	1	23	5 46	1	43
0 57	1	9	6 29	1	102
1 06	1	8	8 11	1	62
1 14	1	14	9 13	1	23
1 28	1	52	9 36	1	
2 18 — 2 22	2	15			

TABLE V. INTERVALS BETWEEN THE SUCCESSIVE TIMES OF EARTHQUAKE OCCURRENCE.

Time Interval.	Number of Earthquakes at				Sum.
	Kagoshima.	Gifu.	Nemro.	Akita.	
5m	11	28	3	1	43
6	7	24	9	5	45
7	8	21	4	5	38
8	9	36	12	1	58
9	7	44	5	6	62
10	10	40	9	1	60
11	14	44	9	4	71
12	8	34	4	3	49
13	12	36	10	2	60

Time Interval.	Number of Earthquakes at				Sum.
	Kagoshima.	Gifu.	Nemro.	Akita.	
14^m	4	23	4	0	31
15	10	24	5	2	41
16	1	22	6	2	31
17	3	30	3	3	39
18	2	25	4	0	31
19	6	19	6	0	31
20	3	19	1	2	25
21	4	16	4		24
22	3	16	5	3	24
23	4	11	2	2	19
24	2	11	3	1	17
25	3	12	2		17
26	1	12	2		15
27	2	6	2	1	11
28	1	12	2	1	16
29	5	11	3		19
30	2	7	0		9
31	0	7	7	1	15
32	1	5	3		9
33	0	11	0	1	12
34	1	8	2	1	12
35	0	3	2	1	6
36	2	6	2		10
37	0	5	0	1	6
38	1	8	0	1	11
39	0	9	1		10
40	1	6	2		9
41	1	5	2		8
42		5	2		7

Time Interval.	Number of Earthquakes at				Sum.
	Kagoshima.	Gifu.	Nemro.	Akita.	
43^{m}	1	7	1		9
44		4	1		5
45		4	1		5
46		3	5		8
47		3	1		4
48		5			5
49		6			6
50		5	1		6
51		1		1	2
52	1	3	1		5
53		4	2		6
54		1	1		2
55		2			2
56		7			7
57		5			5
58		5	1		6
59		1			1
60		1			1
61		4			4
62	1	2	2		5
63		2	1		3
64		1	1		2
65		2			2
66		0	1		1
67		1		1	2
68		1		1	2
69		0		1	1
70		1			1

CHAPTER II. SAKURA-JIMA EARTHQUAKES OBSERVED IN NAGASAKI, OSAKA, AND TOKYO.

6. *Sakura-jima volcanic earthquakes observed in Nagasaki and Osaka.* Tables V and VI give the lists of the volcanic earthquakes attending the Sakura-jima eruption of Jan. 1914, observed instrumentally at the meteorological observatories of Nagasaki and Osaka, whose position were as follows :—

	Latitude.	Longitude.	Distance and Direction from the centre of Sakura-jima.
Nagasaki, ...	32° 44′ 03″ N.	129° 52′ 31″ E.	148 km., N. 30° W.
Osaka, ...	34° 39′ N.	139° 26′ E.	560 km., N. 51° E.

The principal registering instruments at the two places were Omori horizontal pendulum tromometers with E.W. and N.S. components; the pointer magnifications at Nagasaki being 20 and 120, and those at Osaka also 20 and 120. At Nagasaki, 44 of the volcanic earthquakes were observed in the course of the 12 days between the 9th and the 20th of January (1914), only the earthquake at 6½ P.M. on the 12th being there sensible and *rather moderate* in intensity. At Osaka, the number of the shocks recorded, which were all unfelt, was 13, the last occurring at 4 P.M. on the 13th.

As will be seen from Table VIII, the frequent occurrence of the earthquakes in Nagasaki came to an end at 9 A.M. on the 12th. This means that the frequency of the volcanic fore-shocks of the stronger class was much reduced at or immediately prior to the opening of the eruption. This inference, also to be drawn from the list of the earthquakes observed in Osaka, is in accordance with the seismographic observations at Kagoshima (§ 2).

The 6-hourly seismic number in Kagoshima, Nagasaki, and

TABLE VI. HOURLY NUMBER OF THE SAKURA-JIMA EARTHQUAKES INSTRUMENTALLY REGISTERED AT THE NAGASAKI METEOROLOGICAL OBSERVATORY. JAN. 1914.

Day. / Hour.	9	10	11	12	13	14	15	16	17	18	19	20
0—1 A.M.			1	1								
1—2				1	2							
2—3												
3—4												
4—5			2									
5—6			1	1				2				
6—7				1								
7—8								1				
8—9				2				1				
9—10			1									
10—11												
11—12												
0—1 P.M.			2				1					
1—2							1					
2—3		1	1				1					
3—4												
4—5	1				2							
5—6			1									
6—7			1	1			1			1		
7—8		1	5									
8—9			2									
9—10			2									1
10—11			2									
11—12			1									
Sum.	1	2	22	7	4	0	4	4	0	1	0	1

Osaka, is given in Table VII. The course of the frequency variation in Nagasaki is much similar to that of the weak and strong shocks in Kagoshima. (See fig. 4.)

The violent shock at 6½ P.M., on the 12th, is to be regarded, not as a fore-shock, but as a great seismic disturbance probably caused by a stress relieving due to the Sakura-jima eruption at the completion of the explosive stage.

7. *Tromometer observation in Tokyo.* Several of the precursory earthquakes were recorded by the tromometers in Tokyo, the diagrams being, however, unfortunately confused by the pulsatory oscillations. Thus, for instance, the small disturbance at 10. 03. 18 A.M.; 0. 32. 32 P.M.; 0. 48, 44 P.M.; 3. 00. 33 P.M.; and 3. 59. 32 P.M. correspond respectively to the commencements of the principal portion of the strong or moderate Sakura-jima earthquakes, whose times of occurrence at the Kagoshima meteorological observatory were 9. 57. 45 A.M.; 0. 27. 11 P.M.; 0. 43. 00 P.M.; 2. 54. 50 P.M.; and 3. 52. 10 P.M. It is likely that, had the ground in Tokyo been entirely free from the pulsatory oscillations, most of the strong and moderate shocks about 40 in number, would have been clearly registered at the Seismological Institute (Tokyo), whose distance from the centre of the Sakura-jima is 958.6 km.

TABLE VII. 6-HOURLY NUMBER OF THE SAKURA-JIMA EARTHQUAKES INSTRUMENTALLY REGISTERED IN NAGASAKI, OSAKA, AND KAGOSHIMA.

Date. Jan. 1914.	Nagasaki.	Osaka.	Kagoshima.		
			Unfelt.	Slight.	Weak, Strong, and Violent.
11th.	4	1	9	7	3
	1	2	16	11	2
	4	2	58	22	7
	13	4	44	71	17

Date.	Nagasaki.	Osaka.	Kagoshima.		
			Unfelt.	Slight.	Weak, Strong, and Violent.
12th.	3 3 0 1	0 3 0 2	36 53 19 0	61 58 1 1	5 5 0 1
13th.	2 0 2 0	1 0 0 0			
14th.	0 0 0 0				
15th.	0 0 3 1				
16th.	2 2 0 0				

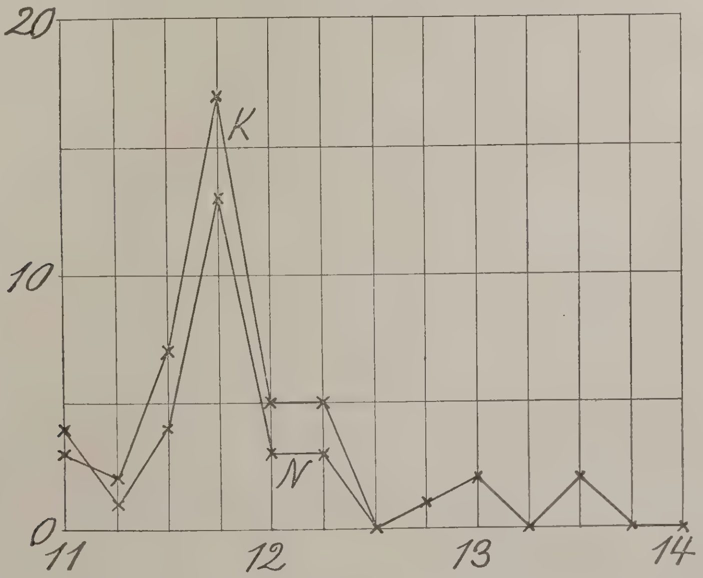

Fig. 4. 6-hourly Frequency Variation of the Sakura-jima Earthquakes tromometrically registered in Nagasaki (N) compared with that of the Sensible Shocks in Kagoshima (K). Jan., 11th to 14th, 1914.

TABLE VIII. LIST OF THE SAKURA-JIMA EARTHQUAKES OBSERVED AT THE NAGASAKI METEOROLOGICAL OBSERVATORY, ON JAN. 9TH—20TH, 1914.

Date and Time of Eqke. Comm't. in Nagasaki.	Compt.	Duration of Prel. Tremor.	Total. Duration
Jan. 9th.			
$^{\mathrm{h}}\ ^{\mathrm{m}}\ ^{\mathrm{s}}$			$^{\mathrm{m}}\ ^{\mathrm{s}}$
4 14 17 P.M.	E.W.		2 23
Jan. 10th.			
2 13 48 P.M.	,,		1 02
7 04 23	,,		
Jan. 11th.			
0 09 31 A.M.	,,		2 42
4 02 48	,,		19
4 27 29	,,		4 12
5 59 12	N.S.		5 02
,, ,, ,, *	E.W.	17^{s}	4 00
9 57 44	N.S.		
0 27 48 P.M.	,,		
0 43 06	,,		
2 55 09	,,		
5 24 17	,,		
6 25 09	,,		
7 21 16	,,		
7 30 17	,,		
7 42 26	,,		
7 51 17	,,		
7 59 43	,,		
8 11 59	,,		
8 23 38	,,		
9 00 00	,,		
Jan. 11th.			
$^{\mathrm{h}}\ ^{\mathrm{m}}\ ^{\mathrm{s}}$			
9 08 14 P.M.	N.S.		
10 25 36	,,		
10 56 26	,,		
11 30 47	,,		
Jan. 12th.			
0 40 21 A.M.	,,		
1 32 10	,,		
5 49 44	,,		
6 03 00	,,		
8 27 31	,,		
8 39 35	,,		
6 28 37 P.M.†	,,	7^{s}	$51^{\mathrm{m}}\ 7^{\mathrm{s}}$
Jan. 13th.			
1 02 38 A.M.	E.W.		51
4 09 38 P.M.	N.S.		4 40
,, ,, ,,	E.W.		4 50
4 46 20	N.S.		1 53
,, ,, ,,	E.W		4 13
Jan. 15th.	,,		
0 56 16 P.M.	,,		
1 44 42	,,		
2 04 04	,,		
6 09 21	,,		

* Max. $2a=0.012$ mm., $T=9.0$ sec., Time of Occurrence $=5.59\ 15$ A.M.

† Max. $2a=9.04$,, , $T=6.0$,, , ,, $=6.28.44$ P.M.

Date and Time of Eqke. Comm't. in Nagasaki.	Compt.	Duration of Prel. Tremor.	Total. Duration	Date and Time of Eqke. Comm't. in Nagasaki.	Compt.	Duration of Prel. Tremor.	Total. Duration
Jan. 16th.				Jan. 18th.			
h m s 5 13 32 A.M.	E.W.		m s 2 10	h m s 6 57 13 P.M.	E.W.		m s 1 53
5 56 11	„			Jan. 20th.			
7 02 05	„			9 06 14 P.M.	„		7 07
8 03 32	„			„ „ „	N.S.		6 39

TABLE IX. LIST OF THE SAKURA-JIMA EARTHQUAKES OBSERVED AT THE OSAKA METEOROLOGICAL OBSERVATORY, ON JAN. 11TH—13TH, 1914.

Date and Time of Eqke. Commencement in Osaka.	Duration of Preliminary Tremor.	Total Duration.	Maximum Motion.		
			Time of Occurrence.	2*a*	*T*
Jan. 11th.					
h m s 4 04 49 A.M.	m s 1 13	m s 13 04	h m s 4 06 29 A.M.	mm 0.024	sec. 4.8
6 00 57	1 12	15 00	6 04 52	0.054	6.2
10 04 21	1 14	18 50	10 08 21	0.072	7.2
0 49 46 P.M.	1 12	12 30	0 53 39 P.M.	0.044	6.2
3 02 23	1 12	10 15	3 05 51	0.040	6.2
6 30 29	1 12	10 20	6 33 12	0.034	4.0
8 30 31	1 13	10 5	8 34 02	0.040	4.8
9 15 49	1 14	8 35	9 18 51	0.060	5.0
10 30 51	1 12	9 25	10 54 31	0.032	4.8
Jan. 12th.					
6 10 28 A.M.	1 12	10 30	6 13 30 A.M.	0.054	4.0
8 34 05	1 13	12 15	8 37 40	0.044	5.2
6 29 28 P.M.	1 10	79 51 81 50	6 33 24 P.M. 6 33 59	7.494 8.394	6.2 7.2*
Jan. 13th.					
4 11 55 P.M.		6 9	4 14 45 P.M.	0.014	4.1

* This refers to the E.W. component, all the others relating to the N.S. component.

CHAPTER III. NOTES ON THE DIAGRAMS OF THE EARTHQUAKES OBSERVED ON JAN. 11TH AND 12TH AT THE KAGOSHIMA METEOROLOGICAL OBSERVATORY.

8. *Typical seismograms.* In §§ 9 to 24 are given the elements of motion in the more prominent 24 among the numerous shocks observed at the Kagoshima meteorological observatory on Jan. 11th and 12th, 1914, prior to the commencement of the outburst of the Sakura-jima, as follows:—

				Intensity.	Character.
A, ...	Eqke. No. 178,	Jan. 11th,	9.18 P.M. ;	Unfelt,	sharp.
	,, 220,	,, ,,	11.09 P.M. ;	Slight,	sharp.
	,, 405,	,, 12th,	9.26 A.M. ;	Unfelt.	
B, ...	,, 10,	,, 11th,	4.45$\frac{2}{3}$ A.M. ;	Unfelt.	
	,, 11,	,, ,,	4.54 A.M. ;	Unfelt.	
	,, 25,	,, ,,	8.56 A.M. ;	Slight,	quick.
	,, 49,	,, ,,	0.43 P.M. ;	Strong,	quick.
	,, 118,	,, ,,	5.43 P.M. ;	Unfelt,	slow.
	,, 125,	,, ,,	6.01$\frac{1}{2}$ P.M. ;	Slight,	slow.
	,, 143,	,, ,,	7.51 P.M. ;	Moderate.	
	,, 149,	,, ,,	8.11$\frac{1}{2}$ P.M. ;	Unfelt.	
	,, 152,	,, ,,	8.18 P.M. ;	Unfelt.	
	,, 159,	,, ,,	8.34 P.M. ;	Moderate.	
	,, 159′,	,, ,,	8.37 P.M. ;	Unfelt,	slow.
	,, 159″,	,, ,,	8.38 P.M. ;	Slight,	slow.
	,, 176,	,, ,,	9.08 P.M. ;	Moderate,	sharp.
	,, 177,	,, ,,	9.12 P.M. ;	Slight,	slow.
	,, 199,	,, ,,	10.13 P.M. ;	Unfelt,	slow.
	,, 222,	,, ,,	11.14 P.M. ;	Slight,	quick.
	,, 307,	,, 12th,	4.10 A.M. ;	Unfelt,	slow.
	,, 308,	,, ,,	4.23 A.M. ;	Unfelt.	

				Intensity,	Character.
Eqke. No. 314,	Jan. 12th,		4.49 A.M.;	Slight.	
„ 322,	„	„	5.19 A.M.;	Unfelt.	
„ 334,	„	„	5.54 A.M.;	Slight,	quick.

The direction in the early part of the preliminary tremor, at the commencement of the diagram, has been ascertained in the three eqkes. of the (A) group. The duration of the preliminary tremor is given only for those cases in which an earthquake occurred while the recording drum of the seismograph, started by a previous shock, was still moving.

The earthquake motion is, as usual, divided into the *preliminary tremor*, the *principal portion*, and the *tail* or end portion. The range of motion, or double amplitude, is denoted by $2a$, and the complete vibration period by T.

9. *Eqke. No. 178.* The prel. tremor motion at the beginning of the diagram was

0.010 mm.,→S. 37° E.; 0.11 mm. upwards.

The princ. portion was composed of quick vibrations:—

	mm	mm
1st Displacement	0.44,→S. 66° E.;	0.14 upwards.
2nd „ ,.........	0.55,→N. 28° W.;	0.18 downwards.

10. *Eqke. No. 220.* The prel. tremor displacement at the commencement of the diagram was

0.29 mm.,→S. 40° W.; 0.28 mm. upwards.

The princ. portion was active for 4.0 sec,, the quick and the slow vibrations at the commencement of the diagram being as follows:—

		mm	mm
Quick motion.	1st Displt., ...	1.14,→S. 36° W.;	0.28 upwards.
	2nd „ ,........	1.01,→N. 6° E.;	0.28 downwards.

Slow motion.

mm
1st Displt.,........1.60,→S. 55° W.
2nd „ ,........2.20,→N. 18° E.
3rd „ ,........1.36,→S. 20° W.
4th „ ,........1.48,→N. 42° E.

11. ***Eqke. No. 405.*** The prel. tremor displt. at commencement of the diagram was

0.60 mm.,→N. 51° E.; 0.19 mm. downwards.

Slow vibration at the commencement of the princ. portion:—

mm mm
1st Displt.,........1.16,→S. 25° W.; 0.028 downwards.
2nd „ ,........1.22,→N. 14° E.; 0.44 upwards.

12. ***Eqke. No. 25.*** Max. vibration occurred at the commencement of the princ. portion:—

mm mm
1st Displt.,........0.52,→N. 23°W.; 0.14 upwards. (?)
2nd „ ,........0.76,→S. 37° E.

13. ***Eqke. No. 10.*** Displt. at the commencement of the princ. portion: 0.41 mm.→N. 36° E.; 0.13 mm. upwards. Max. motion occurred 0.5 sec. later on: 0.42 mm. (N.S.), 0.38 mm. (E.W.), 0.2 mm. (vert.).

14. ***Eqke. No. 11.*** Total duration=60 sec. The prel. tremor lasted 2.15 sec. in each component and was composed of quick movements of $T=0.11$ sec. (N.S.). The princ. portion:—

mm. sec. sec.
(N. S.) ....Max. $2a=0.64$, $T=0.125$.
(E. W.)........ „ $2a=0.32$, $T=0.115$.
(Vert.) .... „ $2a=0.32$, $T=0.115$, $T=0.19$.

There were also slower vibrations in the three components.

15. ***Eqke. No. 49.*** This was a strong shock whose prel. tremor lasted about 2 sec. The max. (slow) vibration occurred at the commencement of the princ. portion: 1st displt., 1.6 mm.→S., 0.4 mm. upwards, corresponding to the two successive movements of 0.8 mm.→W. and 0.8 mm.→E.; 2nd displt., 4.4 mm.→N.; 0.97 mm. downwards, corresponding to the two movements of 1.64 mm. →W. and 1.72 mm.→E.

16. *Eqke. No.* 159. Princ. portion: 1st displt.$=0.49$ mm.→ S. 38° W.; 2nd displt.$=0.70$ mm.→N. 29° E.

17. *Eqke. No.* 176. Princ. portion: 1st displt.$=0.27$ mm.→ S. 42° W.; 2nd displt.$=0.47$ mm.→N. 27° E.

18. *Eqke. No.* 177. In the N.S. component, the prel. tremor lasted 1.65 sec.; the motion being slightly larger for the next 1.1 sec., with $T=0.088$ sec. In the E.W. compt., the prel. tremor lasted 2.0 sec. In the vert. compt., the motion was comparatively large from commencement. [Princ. portion.] $T=0.10$ sec., $2a=0.2$ mm. (N.S.). $T=0.10$ sec., $2a=0.12$ mm.; $T=0.64$ sec., $2a=0.2$ mm. (E.W.).

19. *Eqke. No.* 199. The prel. tremor lasted 2.25 sec., (N.S.). [Princ. portion.] 1st quick displt. $=0.24$ mm.→S. 25° E.

	sec.	sec.	mm.	sec.	mm.
(N.S.)	$T=0.10$;	$T=0.24$,	$2a=0.24$;	$T=0.54$,	$2a=0.16$.
(E.W.)	$T=0.10$;	$T=0.25$,	$2a=0.2$;	$T=0.73$,	$2a=0.2$.
(Vert.)		$T=0.24$,	$2a=0.18$.		

20. *Eqke. No.* 308. [Prel. tremor.] Duration$=2.05$ sec. (N.S.), 1.8 sec. (E.W.), 2.15 sec. (vert.). In the N.S. compt., $T=0.086$ sec. [Princ. portion.] $T=0.09$ sec., $2a=0.48$ mm. (N.S.); $2a=0.32$ mm.(E.W.). The quick vibrations predominated for 3.9 sec.

21. *Eqke. No.* 314. The displt. at the commencement of the diagram, which was very small, was upwards and directed toward the N.E. [Princ. portion.] The 1st eastward motion of 0.62 mm. corresponded to the two successive displacements of 0.24 mm.→S.

and of 0.24 mm.→N. The 2nd westward motion of 0.82 mm. corresponded to the 0.7 mm. southward motion: the resultant being 1.1 mm.→S. 50°W. In the later part, the motion was as follows:—

sec. mm. sec. mm. sec.
(N.S.) $T=0.5$, $2a=0.9$; $T=0.67$.
(E.W.) $T=0.89$, $2a=0.9$; $T=0.61$, $2a=0.4$; $T=0.73$.
(Vert.) $T=0.48$, $2a=0.16$; $T=0.74$.

The quick vibrations were prominent for about 5 sec. This eqke. continued for 62 sec., when the next shock took place.

22. *Eqke. No. 322.* Duration of the prel. tremor=1.9 sec. (N.S.), 1.9 sec. (vert.). The princ. portion lasted 3.0 sec.: $T=0.10$ sec., $2a=0.1$ mm. (N.S.); $T=0.10$ sec., $2a=0.04$ mm. (vert.).

TABLE X. ELEMENTS OF MOTION IN EQKES. NOS. 118; 143; 149; 152; 222; AND 307.

No.	N.S. Compt.		E.W. Compt.		Vert. Compt.	
	Max. $2a$.	T	Max. $2a$.	T	Max. $2a$.	T
118	mm. 1.9	sec. 0.52 0.11 0.22	mm. 0.60	sec. 0.53	mm. 0.45	sec. 0.55 0.11
143	0.64	—	0.56	0.50	0.20	—
149	0.70 0.40	0.55 0.82	0.44 1.00	0.45 0.40 0.85	0.40 0.13	0.35 1.05
152	0.90 0.46	0.45 0.095	1.08 0.22	0.59 0.095	0.30 0.31 0.25	0.095 0.42 0.24
222	0.14	0.10	0.10	—	0.05	0.16
307	0.60 0.94	0.42 0 86	0.80 —	0.64 0.96	0.25	0.19

23. *Eqke. No. 334.* The prel. tremor motion at the commencement of the diagram was 0.14 mm.→W., 0.1 mm.→N. (?), 0.28 mm. upwards. The 2nd (max.) displt. at the commencement of the princ. portion was 2.5 mm.→S., corresponding to the two successive movements of 0.68 mm.→E., and 0.74 mm.→W.

24. The max. $2a$ and the average period in the princ. portion of the eqkes. Nos. 118 ; 143 ; 149 ; 152 ; 222 ; and 307, are given in Table X, while the durations of the prel. tremor in the different earthquakes are collected in Table XII.

25. *Period of vibration.* The average periods of vibration existing in the principal portion of the different earthquakes, collected in Table XI, may be classified more or less definitely into 4 kinds, whose mean values are respectively

$$p_1 = \overset{\text{sec.}}{\mathbf{0.104}}\,;\quad p_2 = \overset{\text{sec.}}{0.22}\,;\quad p_3 = \overset{\text{sec.}}{\mathbf{0.52}}\,;\ \text{and}\ \ p_4 = \overset{\text{sec.}}{0.85}.$$

These 4 periods found in the horizontal and the vertical components, are approximately in the ratios of 1 : 2 : 4 : 8, with the mean unit length of about 0.11 sec. The vibrations of the p_1 and p_3 periods occurred most frequently, the $2a$ (single component) corresponding to p_3 having the maximum value of 1.9 mm. The p_1 class vibrations also occurred in the preliminary tremor.

The periods here considered are to be regarded as characterizing small earthquake movements on the hilly parts in and about the city of Kagoshima. The large destructive seismic motion as that of the earthquake at 6½ p.m., on Jan. 12th, has probably a period equal to or larger than p_4.

26. *Duration of preliminary tremor.* The mean duration of the preliminary tremor in the different fore-shocks was 1.9 sec. (Table XII), corresponding to the central distance of 14.1 km. This duration is practically identical with that found from the

TABLE XI. SAKURA-JIMA FORE-SHOCKS OBSERVED AT THE KAGOSHIMA METEOROLOGICAL OBSERVATORY: PERIOD OF VIBRATION.

N.S. Component.			E.W. Component.		Vert. Component.	
Prel. Tremor.	Princ. Portion.		Princ. Portion.		Princ. Portion.	
sec.	sec.	sec.	sec.	sec.	sec.	sec.
0.11	0.125	0.22	0.115	0.25	0.115	0.24
0.088	0.11	0.24	0.095		0.11	0.24
0.086	0.10		0.10		0.10	0.19
	0.10	**0.23**	0.10		0.095	0.16
0.095	0.10					0.19
	0.10	max. $2a$ =0.24 mm.	**0.103**		**0.105**	
	0.095		max. $2a$ =0.32 mm.		max. $2a$ =0.32 mm.	**0.20**
	0.09					max. $2a$ =0.32 mm.
	0.103					
	max $2a$ =0.48 mm.					
			0.96			
			0.89			
			0.85			
			0.73			
	0.86		0.73			
	0.82				0.74	1.05
	0.84		**0.83**			
	max. $2a$ =0.94 mm.		max. $2a$ =1.0 mm.			
			0.64			
	0.67		0.64			
	0.55		0.61			
	0.54		0.59			
	0.52		0.53		0.55	
	0.50		0.50		0.48	
	0.45		0.45		0.42	
	0.42		0.40		0.35	
	0.52		**0.55**		**0.45**	
	max. $2a$ =1.9 mm.		max. $2a$ =1.1 mm.		max. $2a$ =0.45 mm.	

Mean Values.

Component.	Prel. Tremor.	Principal Portion.			
	sec.	sec.	sec.	sec.	sec.
N. S.	0.095	0.103	0.23	0.52	0.84
E. W.	—	0.103	0.25*	0.55	0.83
Vertical.	—	0.105	0.20	0.45	1.05* 0.74*
Mean.	0.095	0.104	0.22	0.52	0.85

* The mean values of the most frequently occurring periods are given in thick figures. Asteriscs indicate cases of single occurrence.

tromometer observations in Kagoshima of the volcanic earthquakes which happened subsequent to the commencement of the eruption. (See Chapter IV.)

TABLE XII. DURATION OF PRELIMINARY TREMOR OF THE FORE-SHOCKS OBSERVED AT THE KAGOSHIMA METEOROLOGICAL OBSERVATORY.

Eqke. No.	Duration of Preliminary Tremor in		
	N.S. Compt.	E.W. Compt.	Vert. Compt.
	sec.	sec.	sec.
159′	1.7 ?	1.7 ?	1.7 ?
159″	1.5 ?	1.5 ?	1.5 ?
125	2.1	2.1	2.1
143	1.8	1.8	1.8
152	1.8	1.8	2.4
222	1.7	1.6	1.9
307	1.8	1.7	1.5
308	2.05	1.8	2.15
322	1.9	—	1.9
11	2.15	2.15	—
177	1.65	2.0	—
199	2.25	—	—

27. ***Direction of motion.*** An ordinary Gray-Milne type seismograph proves very useful, amongst the others, in the investigation of the direction of motion of individual vibrations in the preliminary tremor of a strong earthquake.* In the case of a small shock, however, it fails to give satisfactory result in this connection, as the magnification ratios of the pointers are small and as the recording drum is started by the electric contact-maker necessarily some time interval after the commencement, thereby the preliminary tremor being lost in the record partially or entirely. Thus, in the present instance, I was able to ascertain from the seismograms obtained at the Kagoshima meteorological observatory the direction of the preliminary tremor motion at the start of the machine only in the following three cases :—

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* See the Bulletin, Vol. VII, No. 3.

Eqke.	Motion at Commt. of the Diagram.	Motion at Commt. of Princ. Portion.	
		(1st Displt.)	(2nd Displt.)
	mm.	mm.	mm.
No. 405.	0.6→N. 51°E. Downwards.	1.16→S. 25°W. (Slow motion)	1.22→N. 14°E. (Slow motion)
No. 178.	0.1→S. 37°E. Upwards.	0.44→S. 66°E. (Quick motion.)	0.55→N. 28°W. (Quick motion.)
No. 220.	0.29→S. 40°W. Upwards.	1.14→S. 36°W. (Quick motion.) 1.58→S. 55°W. (Slow motion.)	1.01→N. 6°E. (Quick motion.) 2.2→N. 18°E. (Slow motion.)

The origins of the two disturbances Nos. 405 and 220 were thus situated to the N.E. of the Kagoshima met. observatory, at the distance of some 14 km., namely, under the sea off the Osaki-hana promontory. The origin of the eqke. No. 178 was probably inland, to the N.N.W. of Kagoshima.

As will be seen from fig. 5, the directions of the 1st and 2nd displacements of the vibration occurring at the commencement of the principal portion were, in each case, more or less near to that about the commencement of the preliminary tremor. This relation was found also to be true of the volcanic earthquakes tromometrically observed in Kagoshima subsequent to the opening of the eruption. The direction of the initial vibrations of the principal portion may, therefore, be taken as a rough substitute for those of the preliminary tremor, in the indication of the position of the origin of disturbance.

Taking together the directions relating to the preliminary tremor and the commencement of the principal portion in the different earthquakes, the mean values are found to be, (i), S. 33°W.–N. 33°E.; (ii), S. 36°E.–N. 36°W. (See Table XIII and fig. 6.) The majority of the cases belonged to the (1) class and seems to point to the location of the principal submarine origin of the seismic activity to the north of Sakura-jima. (See Chapter IV.) The (ii) class shocks probably originated mostly under the sea to the south of the same " island."

28. ***Amplitude of motion at commencement of principal portion.*** The 2nd displacement of the vibration occurring at the commencement of the principal portion was greater than the 1st displacement in the average ratio of 1.63 : 1. (See Table XIV.) In the earthquakes of the (i) class the 1st displacement was directed almost always toward the S.W., and the 2nd displacement towards the N., E., or N.E.

29. ***Destructive shock of Jan. 12th, (1914), at 6.29*** P.M. This was a large earthquake of non-local character, felt most strongly in the low sea-coast districts of Kagoshima. In the city, 39 buildings were totally destroyed, 130 half-demolished, and 977 partially damaged; the casualty consisting of 96 persons wounded, and 13 killed. In the provincial parts, there were altogether 16 dead, besides 2 killed by the eruption and 27 missing, in the island of Sakura-jima.

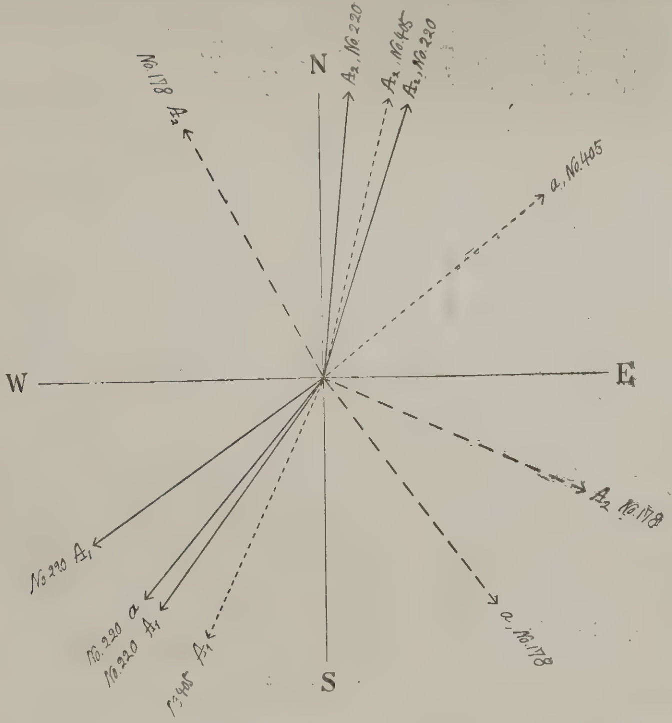
From the record furnished by the ordinary Gray-Milne seismograph at the Kagoshima meteorological observatory (fig. 7), it will be seen that the very first displacement was directed toward the N.W., accompanied by an upward motion. Hence the earthquake origin must have been situated to the S.E. of the observatory. Taking into consideration also the direction of motion in different

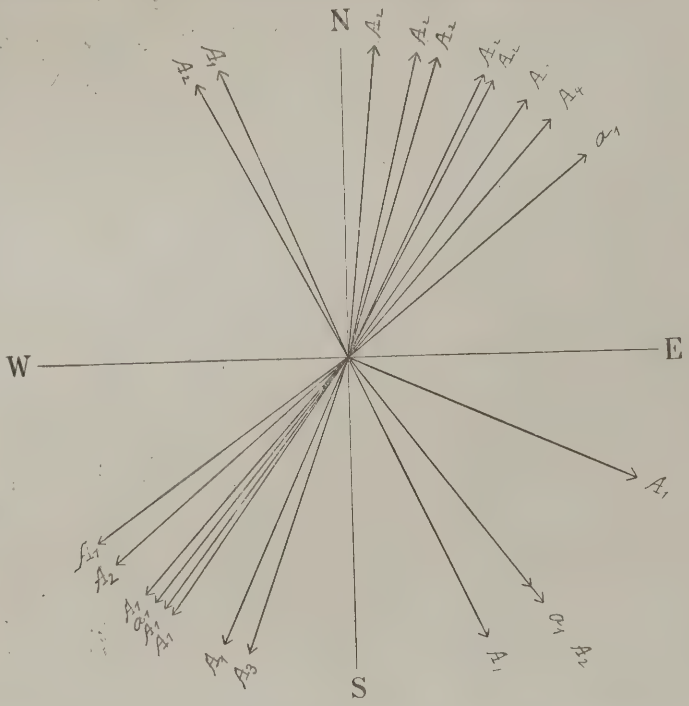
Fig. 5. Earthquakes Nos. 178; 220; and 405.

Fig. 6. Different Earthquakes taken together.

a.............Direction of the preliminary tremor motion at the commencement of the seismogram.

A₁ and **A**₂... Respectively the directions of the 1st and 2nd displacements at the commencement of the principal portion.





Ordinary Seismograph Observation of the Sakura-jima Fore-shocks at the Kagoshima Meteorological Observatory: Direction of the Preliminary Tremor Motion compared with the Directions of the 1st and 2nd Displacements at the Commencement of the Principal Portion.

Fig. 7. Violent Kagoshima and Sakura-jima Earthquake on Jan. 12th, 1914, at 6½ P.M.: the commencement registered on an ordinary Gray-Milne Seismograph at the Kagoshima Meteorological Observatory.

Magnification :—

N. S. and E. W. Components, ... 3.6 times.

Vertical Component ,.................. 7.1 ,,

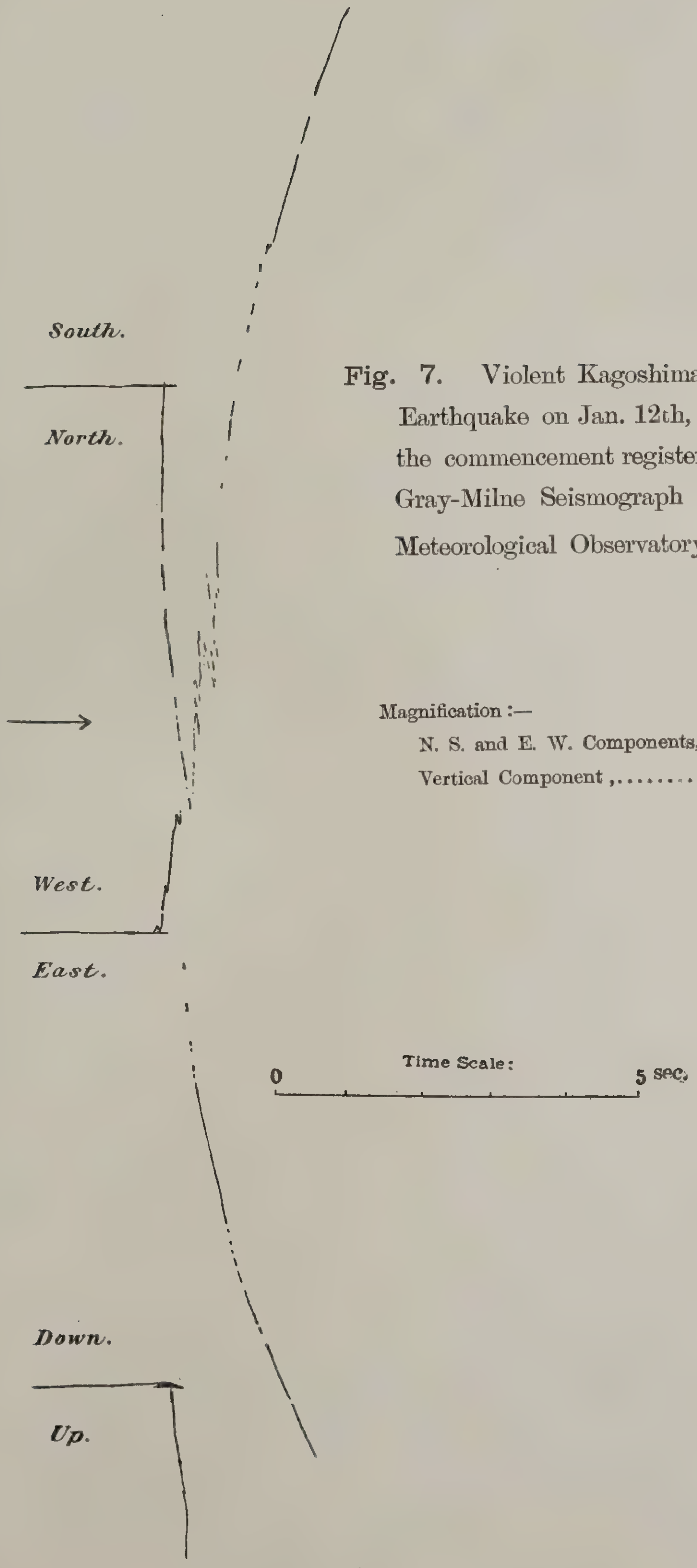


TABLE XIII. SAKURA-JIMA FORE-SHOCKS OBSERVED AT THE KAGOSHIMA METEOROLOGICAL OBSERVATORY: DIRECTION OF THE PRELIMINARY TREMOR MOTION AND THE VIBRATIONS AT THE COMMENCEMENT OF THE PRINCIPAL PORTION.

(i)		(ii)
S. 36° W.	N. 6° E.	S. 25° E.
S. 55° W.	N. 18° E.	S. 66° E.
S. 20° W.	N. 42° E.	S. 37° E.
S. 40° W.	N. 14° E.	S. 37° E.
S. 25° W.	N. 51° E.	N. 28° W.
S. 42° W.	N. 27° E.	N. 23° W.
S. 38° W.	N. 29° E.	
S. 50° W.	N. 36° E.	
S. 33° W.–N. 33° E.		**S. 36° E.–N. 36° W.**

TABLE XIV. KAGOSHIMA OBSERVATION OF SAKURA-JIMA FORE-SHOCKS: COMPARISON OF 1ST AND 2ND DISPLACEMENTS OF THE VIBRATION AT THE COMMENCEMENT OF THE PRINCIPAL PORTION.

	Eqke. No.	1st Displacement $=p_1$	2nd Displacement $=p_2$	Ratio: p_2/p_1
		mm.	mm.	
(i)	10	0.18→W.	0.42→N. 36°E.	2.31
	49*	1.6 →S.	4.4 →N.	2.75
	159	0.49→S. 38°W.	0.7 →N. 29°E.	1.44
	220	1.14→S. 36°W. (Quick motion.)	1.01→N. 6° E. (Quick motion.)	0.89
		1.58→S. 55°W. (Slow motion.)	2.20→N. 18° E. (Slow motion.)	1.39
	314	0.62→E.	1.1 →S. 50 W.	1.78
	334*	1.4 →S.	2.48→N.	1.77
	405	1.16→S. 25°W.	1.22→N. 14°E.	1.05
(ii)	25	0.52→N. 23°W.	0.76→S. 37°E.	1.46
	176	0.27→S. 42°W.	0.59→N. 27°E.	1.83
	178	0.44→S 66°E.	0.55→N. 28°W.	1.24
	199	0.21→S. 25°E.	——	—
			Mean...........................	**1.63**

* Only the N.S. component movements taken into comparison, the corresponding E.W. compt. motion being composed of half-period small movements.

parts of the city of Kagoshima and the position of the strong motion area, the centre of disturbance was probably located at the distance of some 5 km. to the S.E. of the observatory, in the Kagoshima strait and between the former Karasu-jima island and the coast of Kagoshima.

CHAPTER IV. TROMOMETER OBSERVATIONS IN KAGOSHIMA OF THE SAKURA-JIMA AFTER-SHOCKS, OR THE VOLCANIC EARTHQUAKES NOT DIRECTLY ACCOMPANIED BY EXPLOSIONS.

30. ***Tromometer observations.*** A 200-times magnification Omori horizontal tromometer of portable form, which the present author took with him at his first visit to Sakura-jima immediately after the commencement of the eruption in January (1914), was temporarily set up on the solid stone foundation in a room of the Weight and Measure Department, in the compound of the Kagoshima prefectural office, and the observation was started, under the care of my assistant, Mr. H. Krosaka, on the 16th of the same month and continued till Feb. 8th, when the instrument was removed to the village of Frusato in Sakura-jima. The two horizontal pointers of the tromometer were so oriented as to record the movements respectively radial and transverse with regards to the centre of Sakura-jima, namely, parallel to the directions of E. 8°S.-W. 8°N. and N. 8°E.-S. 8°W. These two sets of motion will be styled in the following pages as the E′.-W′. and N′.-S′. components. The natural oscillation period of each of the horizontal pendulums was 4.5 sec.

The list of the daily numbers of the small and large after-eruptions* and of the volcanic earthquakes recorded continuously in Kagoshima has already been given in the Bulletin, Vol. VIII, No. 1. As illustrated in fig. 8, the course of the frequency variation of the large after-eruptions tended to be opposite to those of the small after-eruptions and the non-eruptive volcanic earthquakes.

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* See the Bulletin, Vol. VIII, No. 1.

The volcanic earthquakes not accompanied by explosions or by non-explosive outbursts were composed entirely of quick vibrations and were markedly different in nature from the slow shakings of the ground caused by the explosions.

31. ***Notes on the seismograms.*** In §§ 32 to 40 are given the results of the examination of the original tremor-recorder diagrams (magnification=200) of the following 9 well-recorded Sakura-jima earthquakes of volcanic nature :—

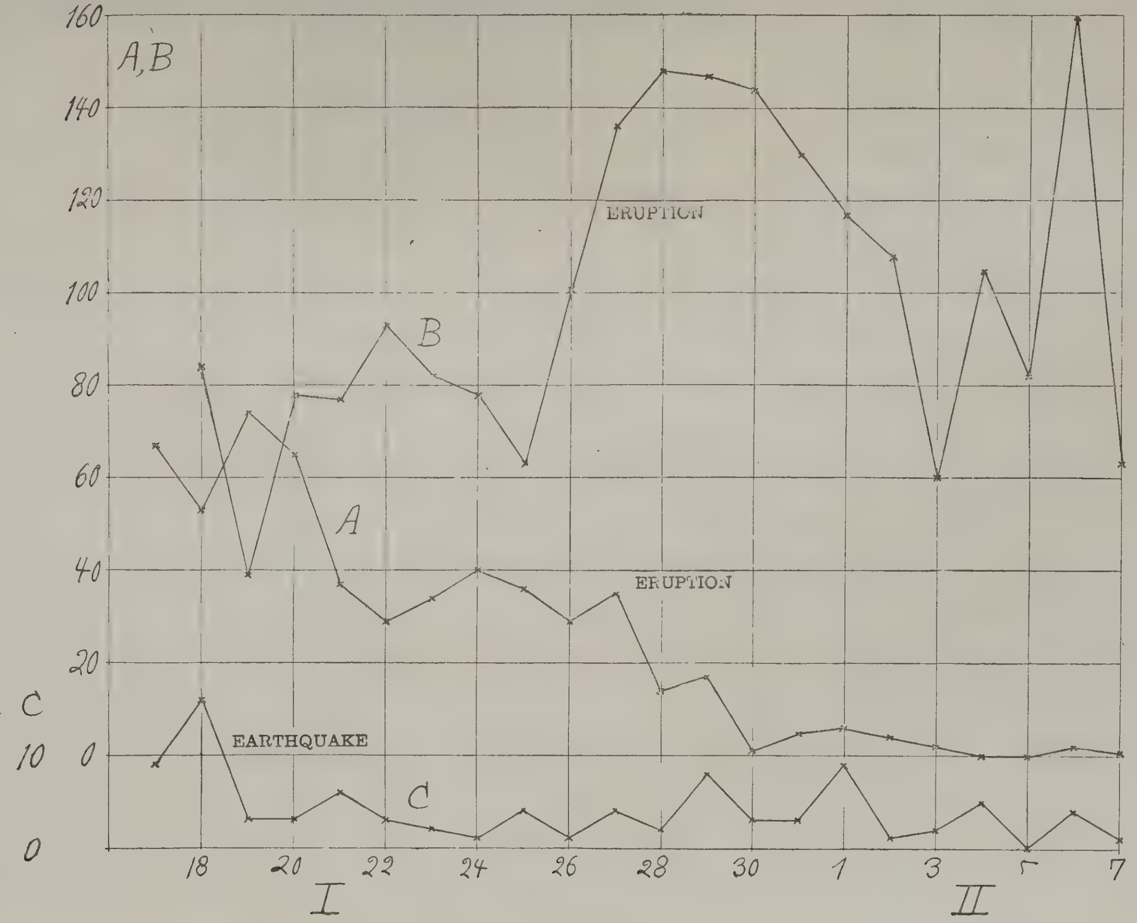
Jan.	23rd,	1914 ;	8.51.55	A.M.
„	24th,	„ ;	8.29.43	A.M.
„	22nd,	„ ;	1.13.17	P.M.
„	28th,	„ ;	5.20.41	A.M.
„	„ ,	„ ;	6.45.38	A.M.
Feb.	1st,	„ ;	7.27.15	A.M.
„	8th,	„ ;	5.34.21	P.M.
Jan.	29th,	„ ;	6.43.58	A.M.
„	21st,	„ ;	10.11.41	P.M.

Each of the first three earthquakes indicated some preliminary tremor, the direction of whose first displacement has been ascertained. On the contrary, the remaining 6 earthquakes began with principal vibrations at once and indicated no preliminary tremor, which either did not actually exist or was else obliterated by the slight motion more or less present at those days of the eruptive activity.

32. ***Eqke. of Jan. 23rd, 1914, at* 8.51.55** A.M. (See fig. 9.) This was a sensible shock composed almost entirely of quick vibrations.

Fig. 8. Daily Frequency Variation of the Sakura-jima After-Eruptions and After-shocks tromometrically observed in Kagoshima. Jan. 17th.—Feb. 7th, 1914.

(A) Larger After-eruptions.
(B) Smaller ”
(C) Non-eruptive Volc. Eqkes.



Total duration=40 sec. [Prel. tremor.] Duration=1.5 sec. Max. $2a=0.027$ mm. (N′. S′.), 0.024 mm. (E′. W′.).

1st Displacement., ... 0.0095 mm.,→S. 43°E.

[Princ. portion.] Duration=4.1 sec. The maximum vibration occurred at the commencement:—

{1st Displt., ... 0.087 mm.,→S. 45°E.
{2nd (max.) Displt., ... 0.15 mm. (N′. S′.), 0.15 mm. (E′. W′.).

$T=0.25$ sec. (N′. S′.), $T=0.28$ sec. (E′. W′.). During the next 12.7 sec., the motion was still active, but became much smaller than before: $2a=0.18$ mm., $T=0.39$ sec. (N′. S′.); $2a=0.019$ mm., $T=0.31$ sec. (E′. W′.). The subsequent motion was slow and very small.

33. *Eqke. of Jan. 24th,* 1914, *at* 8.29.43 A.M. A sensible shock, of total duration=66 sec. [Prel. tremor.] Duration=1.4 sec. During the first 0.69 sec., the motion was small and slow, but during the next 0.69 sec., it was larger and composed of quick vibrations.

1st Displt., ... 0.0046 mm.,→N. 37½°E.
Max. $2a$ (2nd stage)=0.023 mm. (N′. S′.), 0.01 mm. (E′. W′.)

[Princ. portion.] Duration=14.3 sec. The motion was composed of quick movements which were most active at the commencement:

{1st Displt., ... 0.074 mm.,→N. 44°E.;
{4th „ , ... 0.084 „ ,→S. 42°W.

The 2nd displt. was the maximum: $2a=0.11$ mm. in each component. After 26.0 sec. from the commencement, the motion became very small.

34. *Eqke. of Jan. 22nd,* 1914, *at* 1.13.17 P.M. Total duration=96 sec. Duration of the prel. tremor and the princ. portion=26.5 sec. [Prel. tremor.] Duration=2.5 sec. There was no prominent maximum vibration in the princ. portion, the quick movements at the commencement of the prel. tremor being quite large and sharp:

1st well-defined Displt., ...0.015 mm.,→S. 45°W.,

this being preceded by a very small and slow displacement in the opposite direction. Max. $2a=0.02$ mm. (N′. S′.), 0.012 mm. (E′. W′.). [Princ. portion.] The motion was composed of active quick movements for the 1st 7.9 sec. (E′. W′.) and 6.8 sec. (N′. S′.).

35. ***Eqke. of Jan. 28th, 1914, at 5.20.41*** A.M. Total duration =17 sec. There was apparently no prel. tremor, the 1st vibration being the greatest. Duration of the princ. portion, composed of quick vibrations, =9.2 sec. (N′. S′.), 6.2 sec. (E′. W′.).

1st Displt., ...0.026 mm.,→N. 37°E.

The 2nd displacement was the maximum: $2a=0.038$ mm. (N′. S′.), 0.033 mm. (E′. W′.).

36. ***Eqke. of Jan. 28th, 1914, at 6.45.38*** A.M. This was a sensible shock, which indicated apparently no prel. tremor. Duration of the princ. portion, composed of quick movements, was =4.0 sec. (N′. S′.), 1.7 sec. (E′. W′.), the motion ending therewith quite abruptly.

1st Displt., ... 0.023 mm.,→N. 23°E.
2nd „ , (max.)=0.038 mm. (N′. S′.), 0.032 mm. (E′. W′.).

37. ***Eqke. of Feb. 1st, 1914, at 7.27.15*** A.M. The shock was sensible. Total duratien=56 sec. Duration of the prel. tremor= 2.46 sec. [Princ. portion.] Duration=6.1 sec. (N′. S′.), 5.2 sec. (E′. W′.). The motion was composed of quick vibrations.

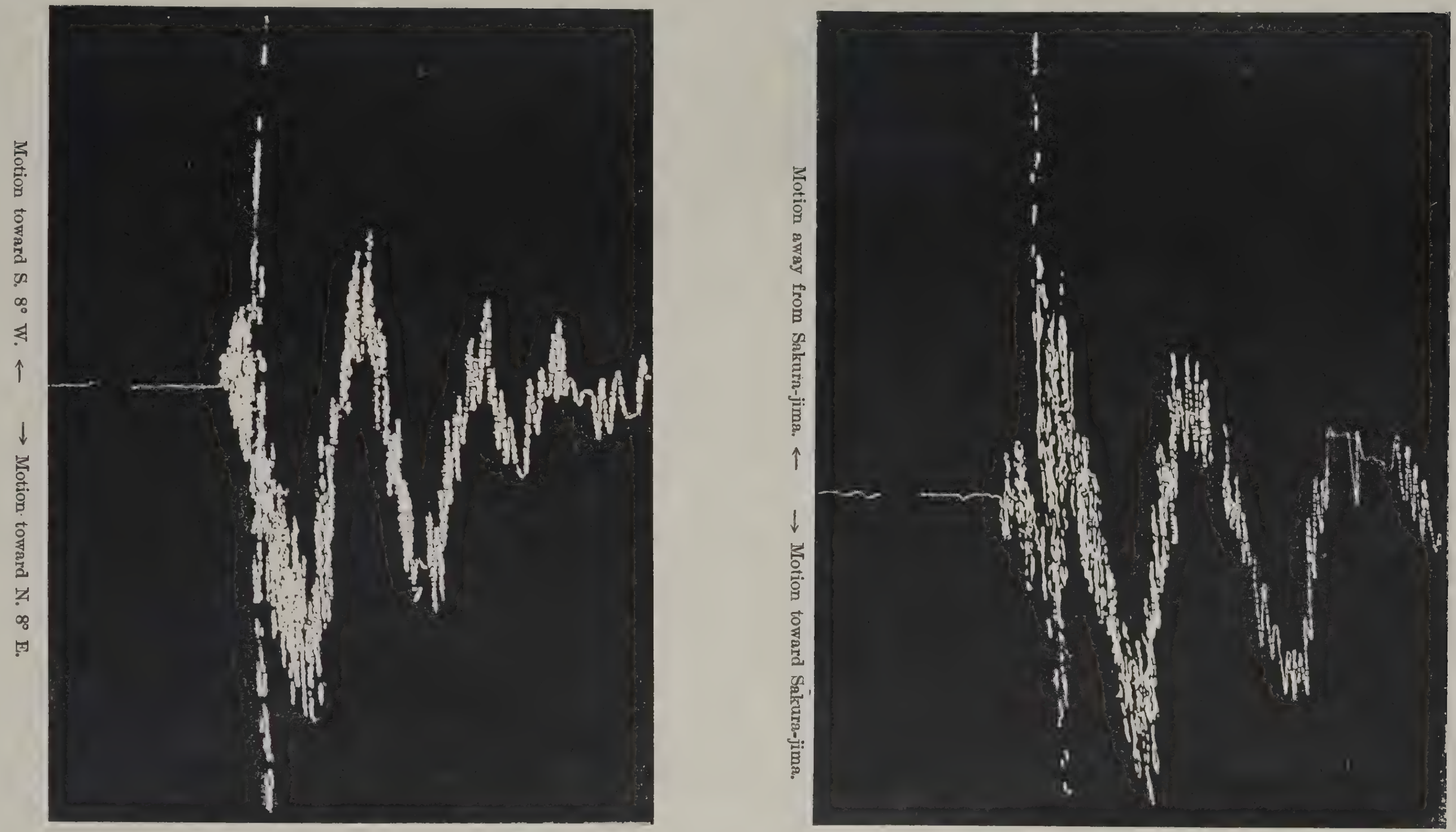
1st Displt., ...0.027 mm.,→S. 50°W.
2nd „ ,........0.033 „ ,→N. 53°E.

$T=0.38$ sec. (E′. W′.). After the princ. portion, there was practically no motion.

Fig. 9. Tromometer Observation in Kagoshima of the Sensible Earthquake on Jan. 23rd, 1914; 8. 51. 55. A. M.

Magnification = 760.

(Photographic enlargement.)



(Time-mark Cutting is shown near the left-hand side in each of the diagrams.)

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38. ***Eqke. of Feb. 8th, 1914; 5.34.21* P.M.** A very small shock of the total duration=18 sec. The prel. tremor was not clearly indicated. [Princ. portion.] Duration=3.0 sec. The motion was composed of quick vibrations.

$\begin{cases} \text{1st Displt.,........0.013 mm.,→S.} \\ \text{2nd ,, ,........0.018 ,, ,→N. 12°W.} \end{cases}$

After the princ. portion there was practically no motion.

39. ***Eqke. of Jan. 29th, 1914; 6.43.58* A.M.** Total duration= 37 sec. There was apparently no prel. tremor. The princ. portion lasted 7.6 sec., the max. vibration occurring at the commencement :—

1st Displt.,........0.017 mm.,→S. 71°E.
Max. $2a=0.045$ mm. (N′. S′.), 0.038 mm. (E′. W′.).

After the princ. portion the motion was slow and very small.

40. ***Eqke. of Jan. 21st, 1914; 10.11.41* P.M.** There was apparently no preliminary tremor, the duration of the princ. portion, composed entirely of quick movements, being 5.4 sec. (N′, S′.), and 3.2sec. (E′. W′.). Max. $2a=0.036$mm. (2nd displt., E′. W′.), 0.03mm. (3rd displt., N′. S′.). In the N′. S′. compt., the motion was most active for the first 1.2 sec., there occurring a second max. group ($2a=0.012$ mm.) 2.8 sec. after the commencement. In the E′. W′. compt., the most active part lasted 1.8 sec., there being no 2nd max. group. The 1st displacement was 0.0283 mm. toward the W′., which corresponded to the two successive movements of 0.0033 mm. toward the N′. and 0.021 mm. toward the S′.; the resultant being 0.034 mm.→S. 66°W. After the princ. portion, the motion became abruptly very small.

41. ***Analysis of the seismograms photographically enlarged.*** Several of the tromometer diagrams of the more prominent volcanic earthquakes have been enlarged photographically 6 or 7

times, with the resultant magnification of about 1,300 times, such that 1 minute time interval corresponded to the linear length of 336 to 500 mm. In §§ 42 to 48 are given the results of analysis of the photographically enlarged diagrams of the following eight seismic disturbances :—

Jan.	22nd,	1914 ;	9.38.45 A.M.
,,	29th,	,, ;	11.41.11 A.M.
,,	,,	,, ;	11.41.52 A.M.
,,	25th,	,, ;	10.49.31 A.M.
,,	29th,	,, ;	6.56.37 A.M.
Feb.	1st,	,, ;	4.42.47 A.M.
,,	8th,	,, ;	11.29.36 P.M.

In the diagrams of the first three earthquakes, the direction of the very first movement in the preliminary tremor has definitely been ascertained ; while in those of the remaining four, the motion began at once with the maximum or large vibration, the preliminary tremor being not distinctly indicated.

42. *Eqke. of Jan. 22nd,* 1914 ; 9.38.45 A.M. Total duration = 60 sec. [Prel. tremor.] The motion lasted 2.1 sec. in each component, and was composed of quick vibrations only, the very 1st displacement being 0.0104 mm. directed toward S. 29° E. Max. $2a=0.023$ mm. (E′. W′.), 0.017 mm. (N′. S′.), occurred 0.52 sec. after the commencement. [Princ. portion.] Duration = 2.1 sec. The maximum quick movements occurred at the commencement :—

1st Displt.,........0.069 mm.,→N. 35° E.
2nd ,, ,........0.136 ,, ,→S. 48½° W.
3rd ,, ,........0.102 ,, ,→N. 55° E.

$T=0.375$ sec. (E′. W′.) ; $T=0.188$ sec. (N′. S′. compt.). During the next 10.6 sec., the vibrations were well-defined, but smaller : $T=0.34$ sec., $2a=0.018$ mm. (E′. W′. compt.). Thereafter the motion, which continued for further 27.6 sec., became abruptly very small and slow.

43. *Eqke. of Jan. 29th,* 1914; 11.41.11 A.M. The duration of the prel. tremor was 1.77 sec. in the E′. W′. and 1.7 sec. in the N′. S′. compt. The 1st vibration was as follows:—

1st Displt.,........0.0212 mm.,→S. 75° W.
2nd „ ,........0.0285 „ ,→N. 66° E.

The princ. portion, 5.4 sec. in duration, commenced with the following max. vibration:—

1st Displt.,........0.12 mm.,→N. 36° E.
2nd „ ,........0.172 „ ,→S. 53° W.

44. *Eqke. of Jan. 29th,* 1914; 11.41.52. A.M. This earthquake occurred 41 sec. after the commencement of the preceding. Total duration =16.7 sec. [Prel. tremor.] Duration =2.5 sec.:—

1st Displt.,........0.0106 mm.,→N. 75° E.
2nd „ ,........0.022 „ ,→S. 81° W.

Max. $2a$=0.026 mm. (E′. W′. compt.); 0.024 mm. (N′. S′. compt.). [Princ. portion.] Duration=2.9 sec. Max. motion occurred at the commencement:—

1st Displt.,....... 0.03 mm.,→N. 87° E.
2nd „ ,........0.093 „ ,→S. 45° W.

The subsequent motion was slow and small.

45. *Eqke. of Jan. 25th,* 1914; 10.49.31 A.M. An unfelt shock, whose max. vibration occurred at the commencement:—

1st displt., ...0.034 mm.,→N. 43½° E.
2nd „ ,........0.060 „ ,→S. 58° W.
3rd „ ,........0.048 „ ,→N. 60° E.

Duration of the princ. portion, composed of quick vibrations, =7.7

sec. (N′. S′.), 6.4 sec. (E′. W′.). The subsequent motion was very small.

46. *Eqke. of Jan. 29th, 1914; 6.56.37* A.M. The motion was maximum at the commencement:—

1st Displt.,........0.034 mm.,→N. 37½° E.
2nd ,, ,........0.0605 ,, ,→S. 50° W.

The princ. portion, 7.4 sec. in duration, consisted of quick vibrations of $T=0.132$ sec. (N′. S′. compt.). The subsequent motion was small and slow.

47. *Eqke. of Feb. 1st, 1914; 4.42.47* A.M. Total duration = 31 sec. Maximum movements occurred at the commencement:—

1st Displt.,........0.0169 mm.,→S. 45° W.
2nd ,, ,........0.0335 ,, ,→N. 55° E.
3rd ,, ,.......0.0355 ,, ,→S. 55° W.

The subsequent motion was much smaller:—

$T=0.39$ sec., $2a=0.0106$ mm., (E′. W′. compt.).
$T=0.27$ sec., $T=0.34$ sec., $2a=0.018$ mm., (N′. S′. compt.).

48. *Eqke. of Feb. 8th, 1914; 11.29.36* P.M. Total duration = 8.3 sec. Duration of the prel. tremor = 2.1 sec. [Princ. portion.] Maximum movements occurred at the commencement:—

1st Displt.,.......0.035 mm.,→S. 66½° W.
2nd ,, ,........0.059 ,, ,→N. 60° E.
3rd ,, ,.......0.036 ,, ,→S. 47° W.

The princ. portion was composed of quick vibrations and lasted 3.4 sec., the subsequent motion being much smaller and slower.

49. *Duration of Motion.* The mean duration of the preliminary tremor in the different volcanic after-shocks mentioned in the preceding §§ was 1.94 sec., as follows:—

Duration of Prel. Tremor.	1st displt. of prel. tremor directed
1.50 sec.	toward S.E.
1.72	,,
2.04	,,
2.11	,,
1.40	toward N.E.
1.74	,,
2.50	,,
2.00	
2.46	
1.94 (mean)	

The corresponding focal distance is 14.4 km., which is exactly the distance from the observing place (Kagoshima prefectural office) from the main centre of the seismic disturbances assumed in § 51. It follows that the focal depth was very small. Consequently, the thickness of the surface layer of the earth's crust over the lava "reservoir" under the inner Kagoshima bay, must be also small.

The duration of the principal portion, generally not much different in the N′. S′. and the E′. W′. components, was most frequently included between 3 and 9 sec., as follows:—

	sec.	sec.	sec.
Duration of Princ. Portion (N′. S′. Compt.)	=2.1	4.1	7.7
	2.9	5.4	9.2
	3.0	5.4	14.3
	3.3	6.1	20.0
	3.4	7.4	26.5
	4.0	7.6	

The total earthquake duration was mostly under 60 sec., with the mean of about 40 sec., as follows:—

	sec.	sec.	sec.
Total Duration.	=8.3	31	60
	16.7	37	66
	17.	40	96
	18.	56	

50. *Period of vibration.* The mean values of the periods of vibration occurring in the different earthquakes were (i) 0.33 sec., and (ii) 0.16 sec., as follows :—

(i) sec.		(ii) sec.
0.254	mean, **0.33** sec.	0.132
0.267		0.188
0.280		**0.16** sec.
0.305		
0.340		
0.335		
0.375		
0.387		
0.392		

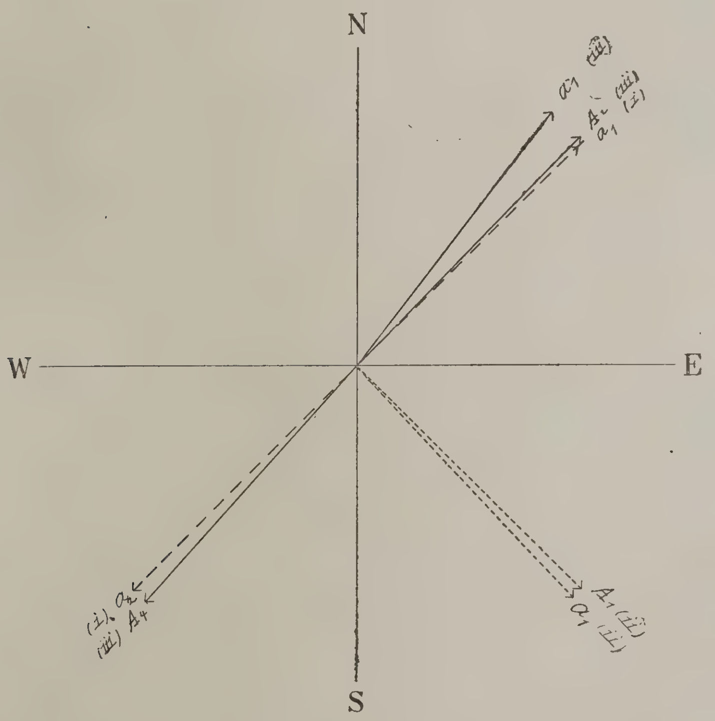
The (ii) period is half of the (i) period.

These periods may be regarded as characterizing the place of observation, in the prefectural compound, where the soil is low and soft, and are different from those at the Kagoshima meteorological observatory (old site) standing on the top of a hill (§ 1).

51. *Direction of motion.* (See figs. 10, 11, and 12.) The direction of motion of the vibrations at the commencement of the preliminary tremor and the principal portion have been ascertained in 6 cases, as in Table XV.

Fig. 10. Tromometer Observation of the Sakura-jima After-shocks in Kagoshima: Vibration Direction at the Commencement of the Preliminary Tremor compared with that at the Commencement of the Principal Portion. (From original diagrams.)

3 Earthquakes: { (i) Jan. 22nd, 1914; 1. 13. 17 P.M.
(ii) „ „ „ ; 8. 51. 55 A.M.
(iii) „ „ „ ; 8. 29. 43 A.M.



Direction of the

a_1....... 1st Displacement, Preliminary Tremor.
A_1........1st „ , Principal Portion.
A_2........2nd „ , „ „
A_4........4th „ , „ „

Tromometer Observation of the Sakura-jima After-shocks in Kagoshima : Vibration Direction at the Commencement of the Preliminary Tremor compared with that at the Commencement of the Principal Portion.

(From photographic enlargements.)

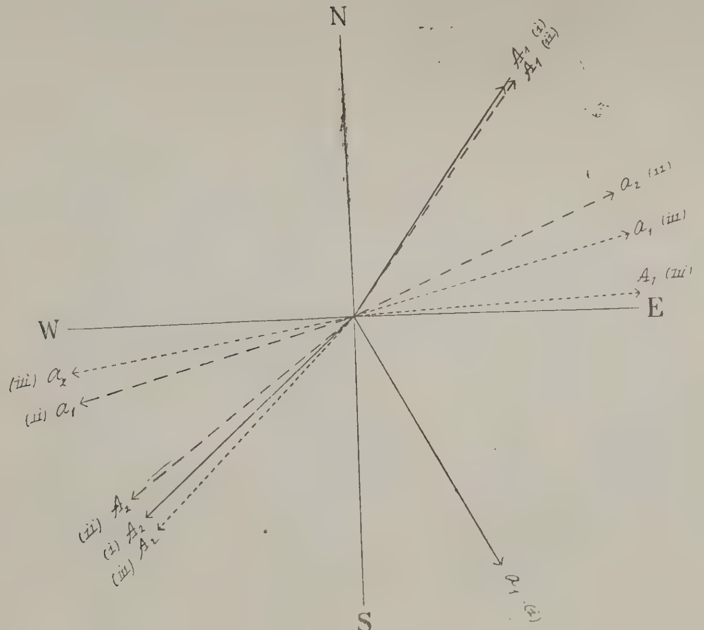


Fig. 11. 3 Eqkes. : (Jan. 1914)
(i) 22nd ; 9. 38. 45 A.M.
(ii) 29th ; 11. 41. 11 „
(iii) „ ; 11. 41. 52 „

Direction of the
a_1........1st Displacement, Preliminary Tremor.
a_2........2nd „ , „ „

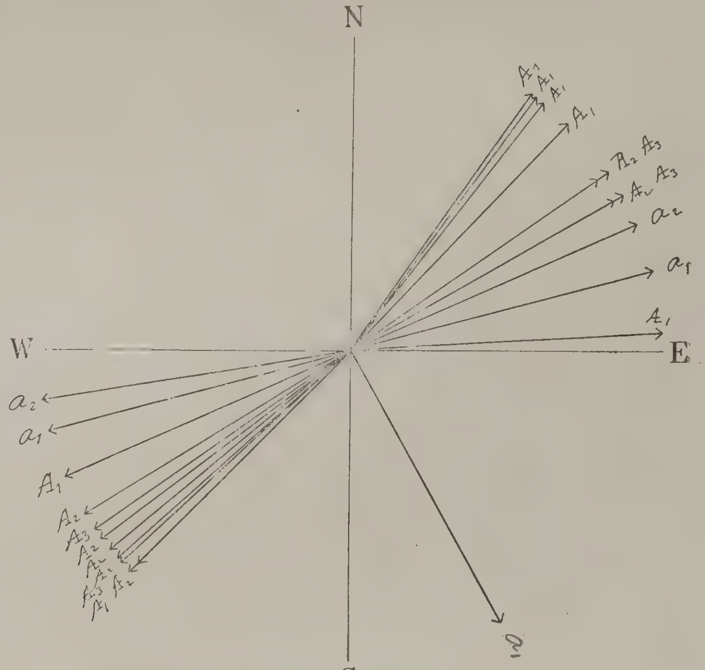


Fig. 12. Different Earthquakes taken together.

Direction of the
A_1........1st Displacement, Principal Portion.
A_2.... 2nd „ , „ „
A_3....... 3rd „ , „ „

In the 3 eqkes. Nos. vi, iv, and ii, the direction of the 1st displacement in the preliminary tremor coincided nearly with that in the principal portion, while in the eqke. No. v, the two directions were roughly opposite. Again, in the 4 eqkes. of the (A) group, the 1st displacement of the preliminary tremor was directed toward the N.E. (in one case, toward the S.W.), and in the two eqkes. of the (B) group, it was directed towards the S.E.; while the direction of the 1st displacement in the principal portion was all directed toward the N.E., except in the one case of (ii), in which it was directed toward the opposite side. I conclude:—*firstly*, that the 1st vibrations in the preliminary tremor and the principal portion were executed mostly in approximately similar directions; and, *secondly*, that the 1st displacement in the principal portion tended to be directed generally toward the N.E. This latter fact is seen also from Table XVI, which gives, for the different earthquakes, the direction and amplitude of the 1st and 2nd displacements of the

TABLE XV. DIRECTION OF THE 1ST VIBRATION IN THE PRELIMINARY TREMOR COMPARED TO THAT IN THE PRINCIPAL PORTION.

Earthquake No.		Date (1914) and Time of Occurrence.	Preliminary Tremor.		Principal Portion.	
			1st Displt.	2nd Displt.	1st Displt.	2nd Displt.
			mm.	mm	mm.	mm.
A	v	Jan. 29th; 11.41 11 A.M.	0.0212→ S.75°W.	0.0285→ N. 66°E.	0.12→ N. 36°E.	0.172→ S.53°W.
	vi	Jan. 29th; 11.41.52 A.M.	0.0106→ N. 75°E.	0.022→ S.81°W.	0.03→ N 87°E.	0.093→ S 45°W.
	iv	Jan. 24th; 8.29.43 A.M.	0.0046→ N.37°½E.	——	0.074→ N. 44°E.	(4th displt.) 0.084→ S.42°W.
	iii	Jan. 22nd; 1.13.17 P.M.	(Small)→ N. E.	0.015→ S 45°W.	——	——
B	i	Jan. 22nd; 9.38.45 A.M.	0.0104→ S. 29°E.	——	0.069→ N. 35°E.	0.130→ S.48°½W.
	ii	Jan. 23rd; 8.51.55 A.M.	0.0095→ S. 43°E.	——	0.087→ S. 45°E.	——

vibration at the commencement of the principal portion. Thus the 1st displacement in question was directed toward the N.E., in the 8 eqkes. of the (I) group, and directed toward the opposite side, or the S.W., in the 4 eqkes. of the group (I′). In the 3 eqkes. of the (II) group, the initial direction was toward the S. or S.E.

Taking together all the determinations relating to the 1st and 2nd displacements of the preliminary tremor and the principal portion, as shown in Table XVII, we obtain the following two mean directions:—

(I) N. 52°.6. E.–S. 52°.6 W. (II) S. 42° E.–N. 42°W.

(I) represented the most frequently occurring direction of motion, and may be taken as indicating the existence of the principal source of seismic disturbance to the N. 52.°6 E. from the site of observation (the prefectural compound, Kagoshima) at the focal distance of 14.4 km. (§ 49). The position thus defined corresponds to a place off the Osaki-hana promontory, and naturally we are led to identify it with the *centre of elevation* of the sea-bottom* to the north of the Sakura-jima, at $\varphi=31°40'$N., $\lambda=130°40'$E., which is situated at the distance of exactly 14.4 km. to the N.54°E. from the observing station. In this connection it may be added that the fore-shocks were felt with a very high frequency at the village of Saido on the north-western coast of Sakura-jima. (See the Bulletin, Vol. VIII, No. 1, p. 11.) (II) may be taken as indicating the existence of a secondary source of submarine seismic disturbance to the south of the "island."

52. *Range of motion.* From Table XVI it is seen that the 2nd displacement of the initial vibration of the principal portion was greater than the 1st in the average ratio of 1.8:1. Confining our attention to the cases of the group (I), the ratio in question

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* See the Bulletin, Vol. VIII, No. 4

TABLE XVI. SAKURA-JIMA VOLCANIC EARTHQUAKES OBSERVED TROMOMETRICALLY IN KAGOSHIMA, JAN. 16TH—FEB. 8TH, 1914: THE VIBRATION AT THE COMMENCEMENT OF THE PRINCIPAL PORTION.

	1st Displacement.	2nd Displacement.
	mm.	mm.
(I)	0.069→N. 35° E.	0.136→S. 48°½ W.
	0.074→N. 44° E.	—
	0.034→N. 43°½ E.	0.060→S. 58° W.
	0.026→N. 37° E.	—
	0.023→N. 23° E.	—
	0.034→N. 37°½ E.	0.061→S. 50° W.
	0.120→N. 36° E.	0.172→S. 53° W.
	0.030→N. 87° E.	0.093→S. 45° W.
(I′)	0.017→S. 45° W.	0.034→N. 55° E.
	0.027→S. 50° W.	0.033→N. 53° E.
	0.035→S. 66°½ W.	0.059→N. 60° E.
	0.034→S. 66° W.	
(II)	0.017→S. 71° E.	
	0.087→S. 45° E.	
	0.013→S.	0.018→N. 12° W.

TABLE XVII. TROMOMETER OBSERVATION OF SAKURA-JIMA VOLCANIC EARTHQUAKES, JAN. 16TH—FEB. 8TH, 1914: DIRECTIONS OF THE 1ST AND 2ND DISPLACEMENTS AT THE COMMENCEMENT OF THE PRELIMINARY TREMOR AND THE PRINCIPAL PORTION.

N. 23° E.	N. 53° E.	S. 42° W.	S. 53° W.	S. 43° E.
N. 35° E	N. 55° E.	S. 45° W.	S. 55° W.	S. 45° E.
N. 36° E.	N. 55° E.	S. 45° W.	S. 58° W.	S. 71° E.
N. 37° E.	N. 60° E.	S. 45° W.	S. 66° W.	S. 29° E.
N. 37° E.	N. 60° E.	S. 48°½W.	S. 66°½W.	S.
N. 37°½E.	N. 66° E.	S. 50° W.	S. 75° W.	N. 12° W.
N. 43°½E.	N 75° E.	S. 50° W.	S. 81° W.	N. 51° W.
N. 44° E.	N. 87° E.	S. 47° W.		
(I) N. 52.°6 E.—S. 52.°6 W.				(II) S. 42°E.—N. 42°W.

comes out to be 2.0:1. These results are what may be expected, as the 1st displacement is of the nature of a simple amplitude and the 2nd of that of the double amplitude.

53. *Comparison with the fore-shocks.* The ordinary seismograph diagrams of the Sakura-jima fore-shocks obtained at the Kagoshima meteorological observatory (Chapter III) was inferior to the continuous tromometer registers of the volcanic after-shocks in the accuracy of the determination respecting the directions of motion. Still the results furnished by the former series of observation was approximately similar to those by the latter; the most active centres of the volcanic fore-and after-shocks being probably identical, and situated under the sea, coincident with the elevation part of the bottom of the inner bay. A feature of special interest is that the maximum displacements at the commencement of the principal portion tended to take place toward, or away from, the centre here assumed, even in some cases in which the 1st movements in the preliminary tremor pointed toward the S.E., with the origin of disturbance in the latter direction. This may be considered as indicating a habit of the Sakura-jima earthquakes, due probably to the facility of the production of prominent movements radially to the sensitive seismic focal area, irrespective of the location of disturbance origins at other points in the vicinity.

The great eruption of Sakura-jima of 1914 may be regarded as the culmination of the powerful volcanic tension which had existed under the volcano and the bottom of the Inner Kagoshima Bay, and the principal eruptive energy has been spent during the first two days of the outburst, Jan. 12th and 13th, when the emission of an immense quantity of smoke, ashes, and pumice, was followed by the outflows of an exceptionally large amount of lava. The eruption took place from the Sakura-jima, but the lava

Diagrams illustrating the Origin of the Fore-shocks and After-shocks of the Sakura-jima Eruption.

LL........Underground Lava Reservoir.
T .... Underground Volcanic Tension.
P ....Pressure of the Surface Earth-crust.
K........Observing Station.

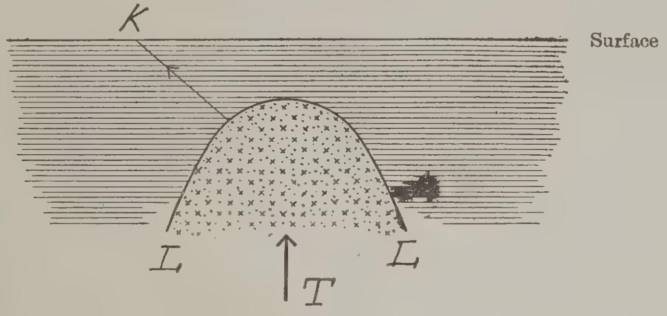

Fig. 13. Origin of a Volcanic *Fore-shock.*

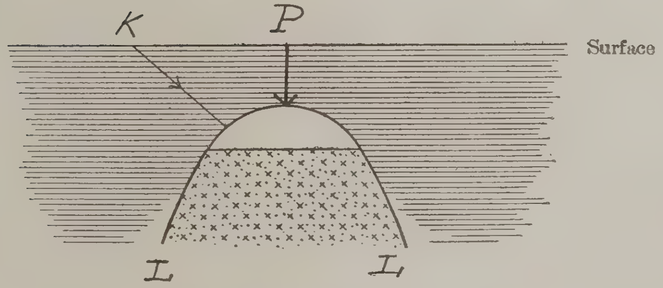

Fig. 14. Origin of a Volcanic *After-shock.*

"reservoir" existed under the inner bay,* where the principal seismic centre was also located. The volcanic fore-shocks on the 11th and 12th of Jan. 1914, were doubtless the result of the upward underground tension, contending to burst open the superincumbent portion of the earth's crust. After the principal eruptive stages, there set in the subsidence of the disturbed region, which tended to push down the superficial portion of the earth's crust spanning over the more or less vacant lava "reservoir," this being probably the main cause of the volcanic after-shocks. Hence, the 1st displacement of the principal or maximum vibration of a volcanic fore-shock ought most naturally to be directed outwards, and that of volcanic after-shocks to be directed origin-wards, as illustrated diagrammatically in figs. 13 and 14. This directional difference is in harmony with the results of the instrumental observations in Kagoshima (§ 51), where the 1st displacement of the principal portion of the fore-shocks was mostly directed towards the S.W., and that of the after-shocks mostly toward the N.E.

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* The Bulletin, Vol. VIII, Nos. 2 and 4.

In the above considerations respecting the direction of motion, it is assumed that the application of the volcanic tension from below did not result in a marked upheaval of a small central area, in which case the 1st displacement ought to be directed inwards, being virtually the first stage in a volcanic explosion.

CHAPTER V. TROMOMETER OBSERVATION IN KAGOSHIMA OF THE SAKURA-JIMA AFTER-ERUPTIONS, JAN. 16TH—FEB. 8TH, 1914.

54. *Observation in Kagoshima.* The compound of the Kagoshima prefectural office, where the tromometer observation has been carried on (§ 30), is situated 10 km. nearly westwards from the centre of Sakura-jima. Its position relative to the craterlets on the two sides of the volcano, which were active at the time concerned, was as follows :—

5.9 km. to the W. 5° N. from the Lowest Craterlet on the W. flank ;
8.5 km. ,, W. 8° N. ,, Highest ,, ,, ;
11.8 km. ,, W. 10° N. ,, No. 2. Craterlet on the S.E. flank ;
14.3 km. ,, W. 11° N. ,, Lowest ,, ,, .

The No. 2 and the lower craterlets on the S.E., or the Nabeyama, side remained active for different long time intervals, while the craterlets on the W. side of the island ceased to be active on or about the 25th of January (1914).

The two pointers of the tromometer were arranged so as to register the motion in the directions W.8°N.–E.8°S., and S.8°W.–N.8°E. These corresponded, with regards to the craterlets, approximately to the longitudinal and the transverse components respectively. In the following §§ are described the instrumental diagrams of a number of the more prominent after-eruptions observed in Kagoshima between Jan. 16th and Feb. 8th, 1914.

55. *After-eruptions on evening of Jan. 16th*, 1914. The maximum movements in some of the larger disturbances were as follows:

Longitudinal Component.	Transverse Component.
0.054 mm.	0.051 mm.
0.054 „	0.047 „
0.042 „	
0.041 „	

56. *Jan. 17th*, 1914; 6.29.03 P.M. The very 1st displacement was 0.0086 mm. toward S. 47°E. [Longit. compt.] During the 1st 2.8 sec., the motion was very small. During the next 4.3 sec.: $T=0.6$ sec., $2a=0.017$ mm. Motion large for the next 21.5 sec.: $T=1.3$ sec., $2a=0.041$ mm. In the subsequent portion: $T=2.5$ sec., $T=1.2$ sec., etc. [Transv. compt.] During the 1st 2.8 sec., the motion was small and slow. For the next 6.9 sec., the motion was small, but active: $T=0.44$ sec., $2a=0.022$ mm.; $T=0.88$ sec. During the next 17.5 sec., the motion was large and composed of slow vibrations of $T=1.8$ sec. ($2a=0.048$ mm,) mixed at first with those of $T=0.57$ sec. In the subsequent portion: $T=2.7$ sec., $T=1.4$ sec., etc.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor, ...	2.8 sec.	2.8 sec.
,, ,, princ. portion, ...	—	36.0
,, ,, specially active part, ...	24.0	16.6
Total duration, ...	over 91.0	73.0

57. ***Jan. 17th*, 1914 ; 6.17.25** P.M. The very 1st displacement was 0.002 mm. directed toward, and the 2nd was 0.01 mm. away from, the Sakura-jima. The distinct motion occurred 6.2 sec. earlier in the longit. than in the transv. component. [Longit. compt.] For the 1st 5.5 sec.: $T=0.9$ sec., $2a=0.01$ mm. In the principal portion: $T=1.11$ sec., $2a=0.036$ mm. [Transv. compt.] The preliminary tremor lasted 6.2 sec. Max. $2a=0.03$ mm., $T=1.0$ sec.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor and princ. portion, ...	41.2 sec.	37.2 sec.
Duration of specially strong portion	21.2	21.0

58. ***Jan. 17th*, 1914 ; 7.13.17** P.M. The 1st displacement was 0.01 mm. directed away from the Sakura-jima. The motion became distinct 4.5 sec. earlier in the longit. than in the transv. component. [Longit. compt.] The motion was definite from the commencement, giving no distinction between the prel. tremor and the princ. portion. $T=1.03$ sec., $2a=0.02$ mm. [Transv. compt.] Max. $2a=0.017$ mm., $T=0.98$ sec.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor and princ. portion, ...	16.4 sec.	11.4 sec.
Total duration, ...	32.0	27.0

59. ***Jan. 18th*, 1914 ; 6.57.04** P.M. The 1st displacement was 0.005 mm. directed away from the Sakura-jima. [Longit. compt.] Prel. tremor lasted 4.1 sec. Active motion set in 6.4 sec. after the start. Max. $2a=0.036$ mm., $T=0.90$ sec, ; $T=1.52$ sec. [Transv.

Fig. 15. Tromometer Observation in Kagoshima of the Sakura-jima After-eruption on Jan. 21st, 1914; 2. 07. 26 P.M.

Magnification = 850. (×) Minute Time-cutting. (Photographic enlargement.)

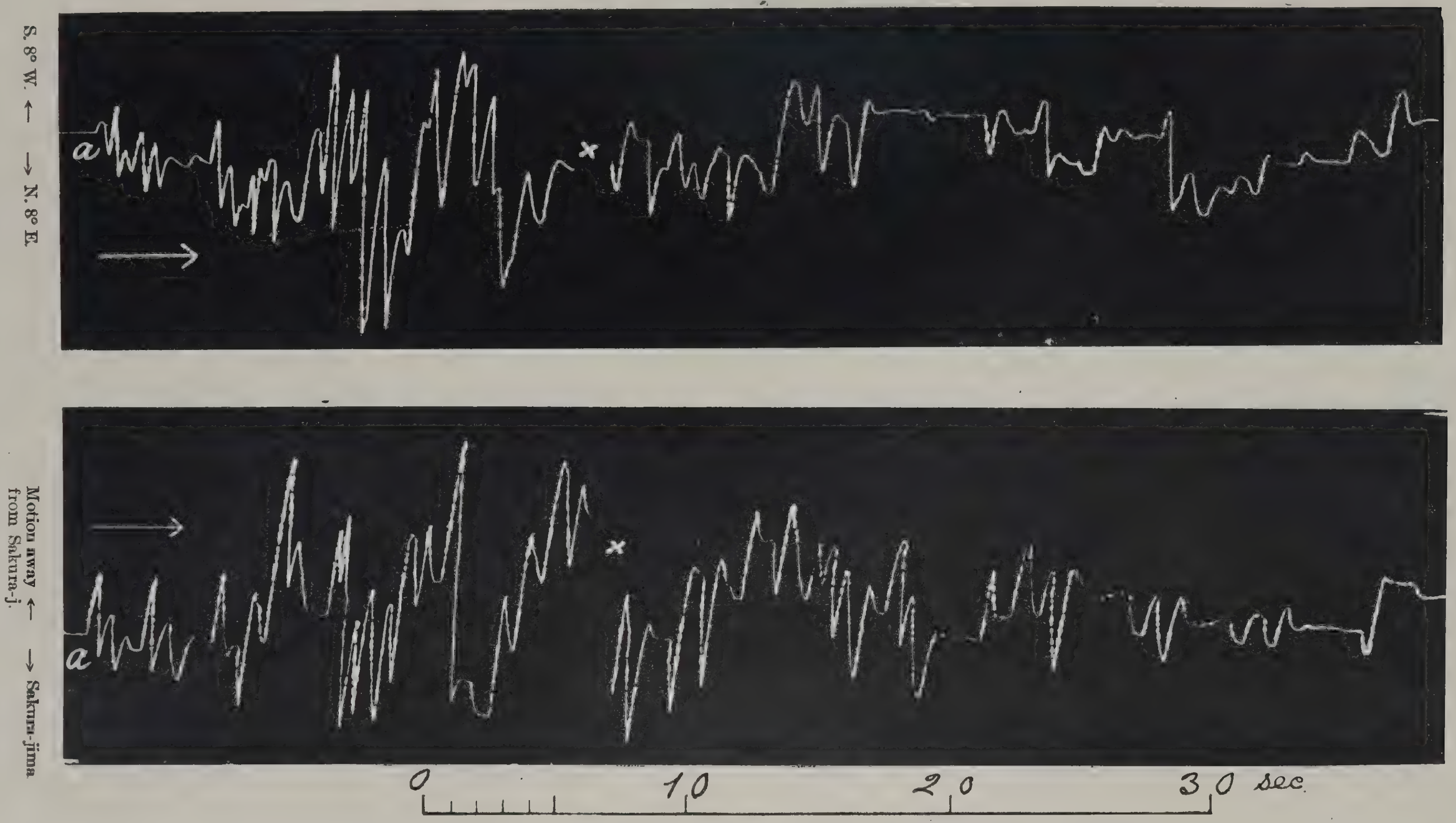

Fig. 16. Tromometer Observation in Kagoshima of the Sakura-jima After-eruption on Jan 21st, 1914; 2. 19. 57 P. M.

Magnification = 700. (×) Time Cutting every 1 minute. (Photographic enlargement.)

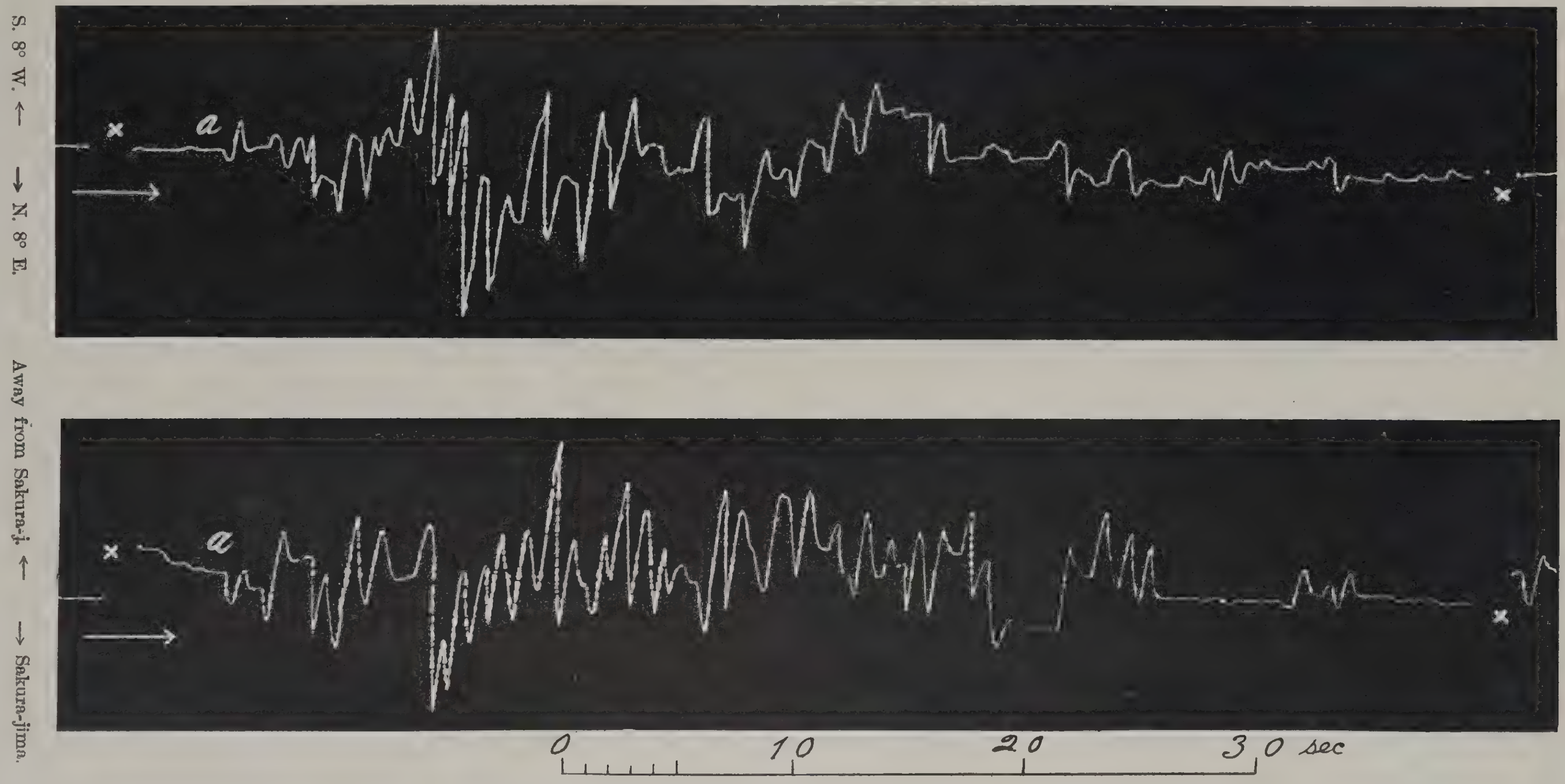

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Fig. 17. Tromometer Observation in Kagoshima of the Sakura-jima After-eruption on Jan. 17th, 1914; 6. 29. 03. P. M.

Magnification = 950. (×) Minute Time-cutting. (Photographic enlargement.)

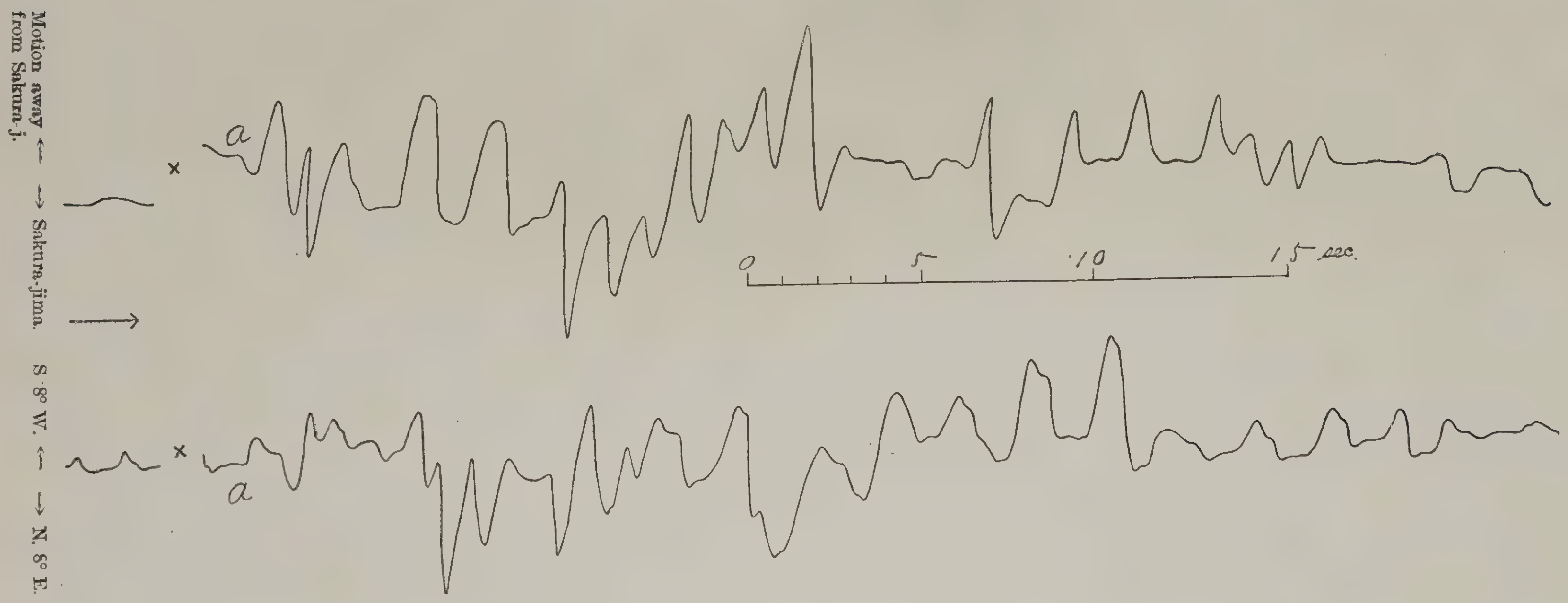

Fig. 18. Tromometer Observation in Kagoshima of the Sakura-jima After-eruption on Jan. 18th, 1914; 6. 35. P. M.

Magnification = 800.   (×) Minute Time-cutting.   (Photographic enlargement.)

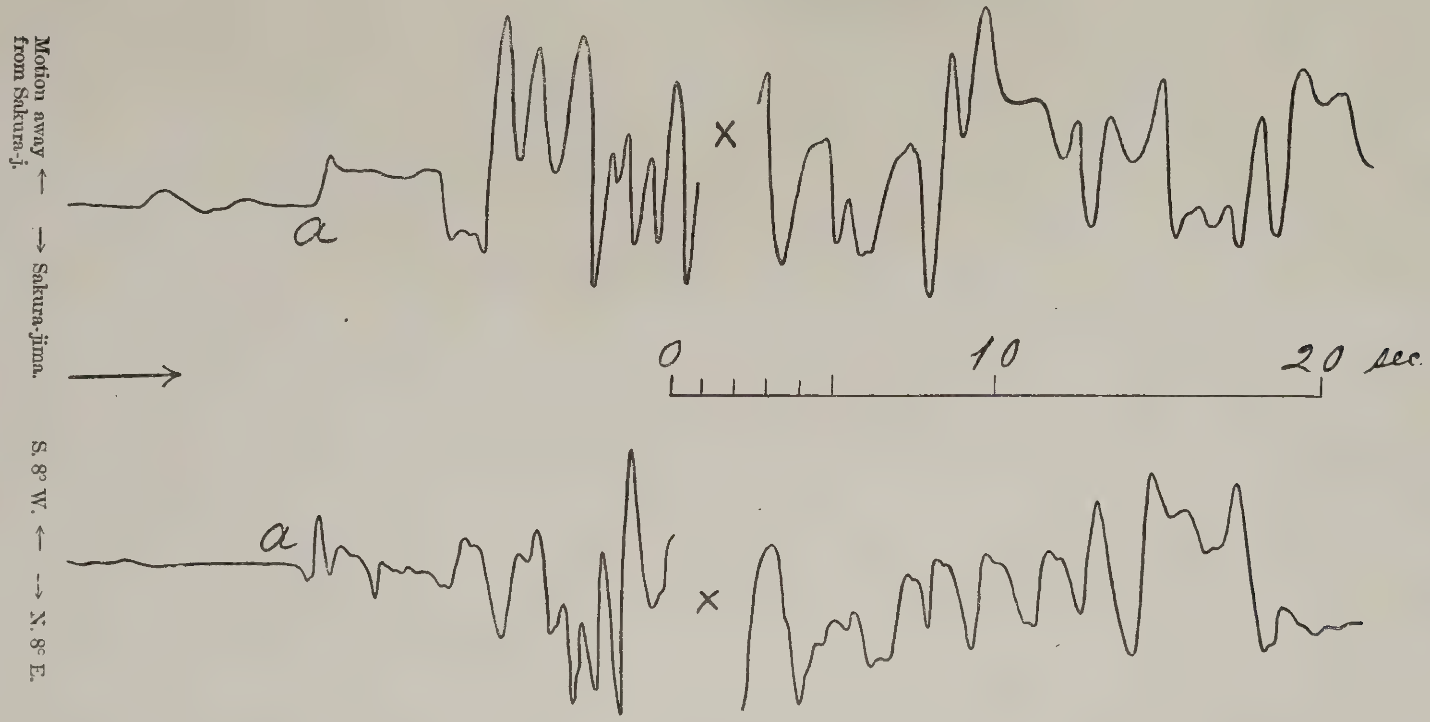

Fig. 19. Tromometer Observation in Kagoshima of the Sakura-jima After-eruption on Jan. 18th, 1916; 6. 07. 42. P. M.

Magnification = 730. (×) Minute Time-cutting. (Photographic enlargement)

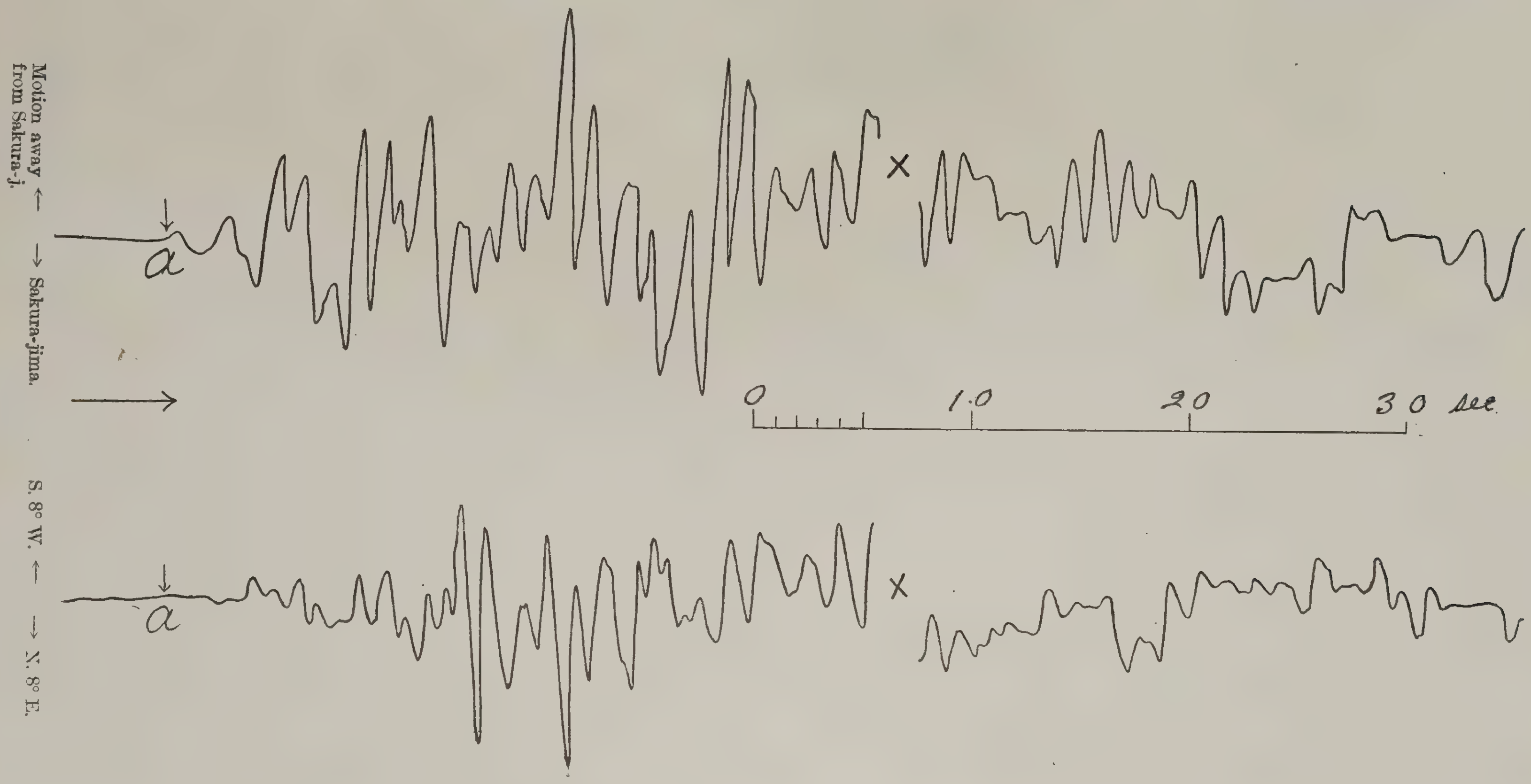

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Fig. 20. Tromometer Observation in Kagoshima of the Sakura-jima After-eruption on Jan. 18th, 1914 ; 7. 15. 40. P. M.

Magnification = 670. (×) Minute Time-cutting. (Photographic enlargement.)

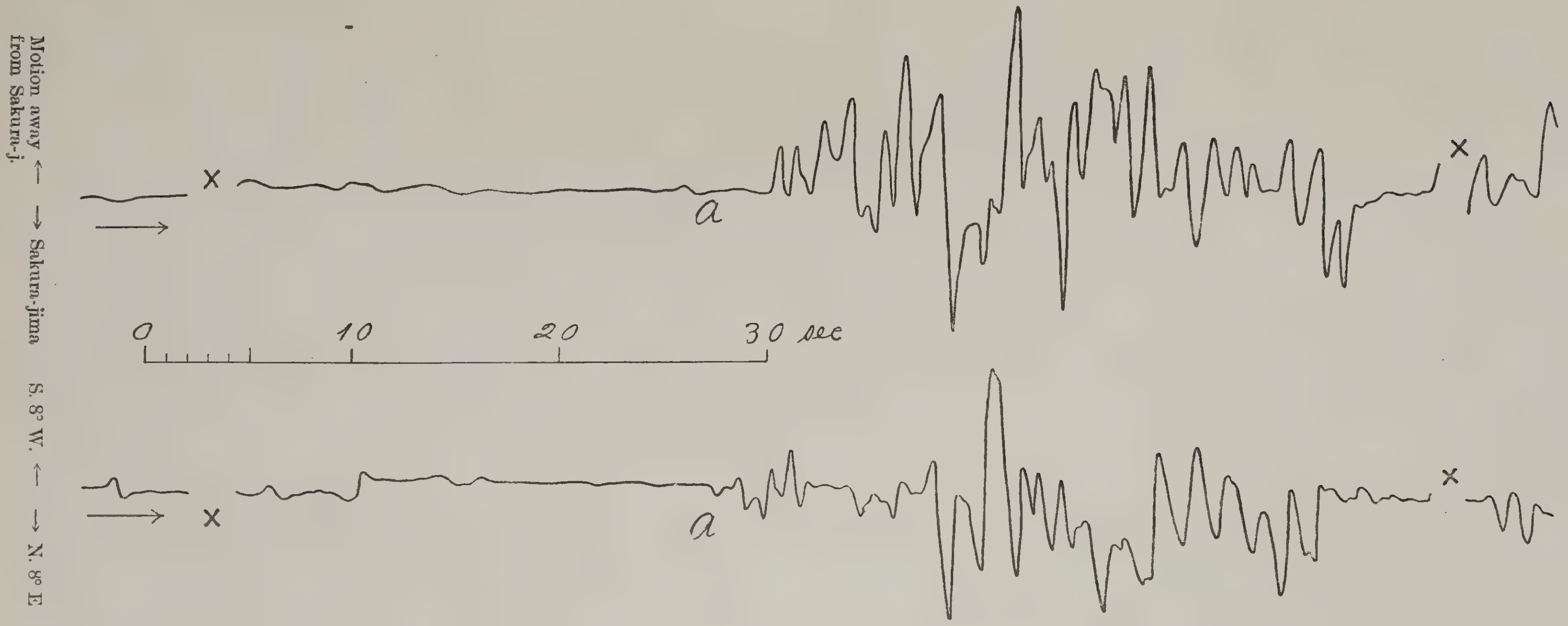

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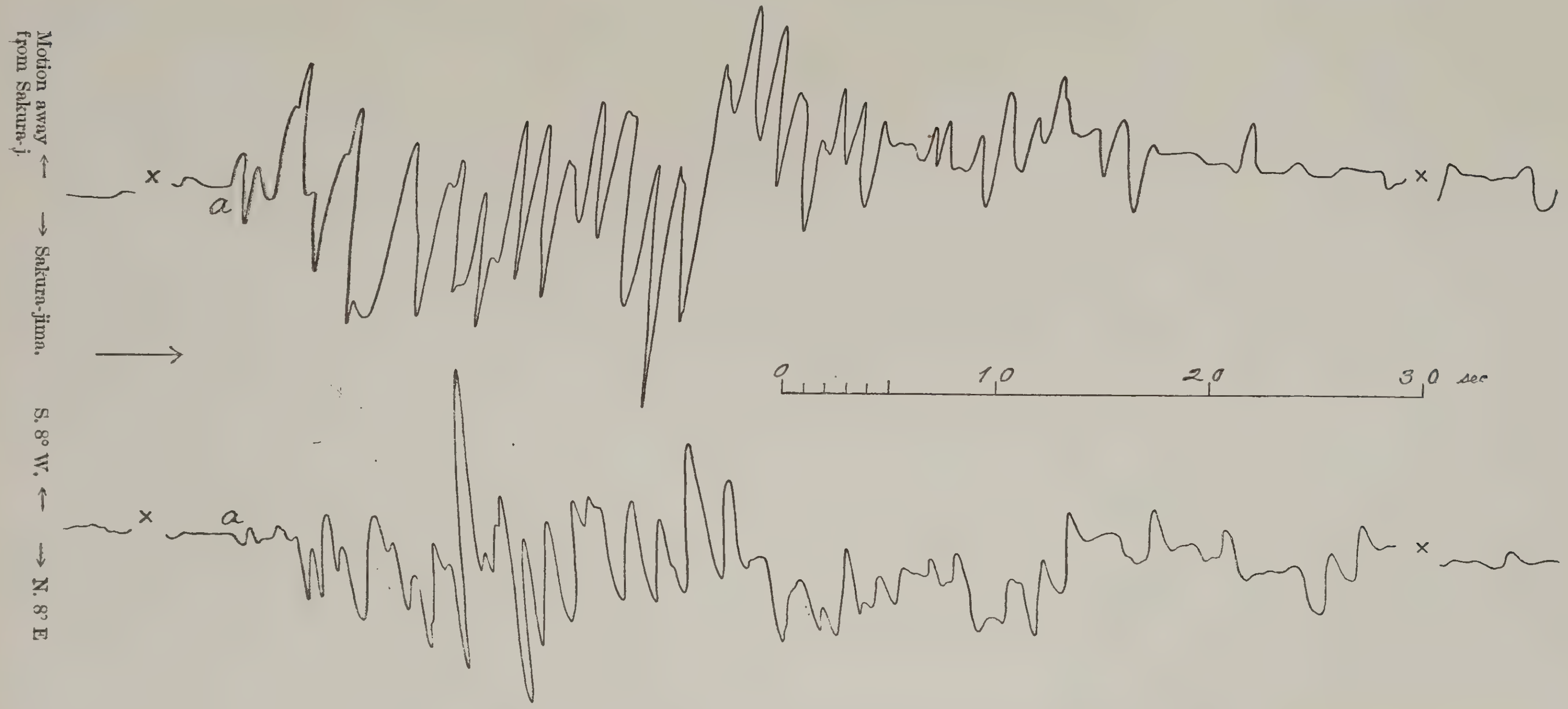
Fig. 21. Tromometer Observation in Kagoshima of the Sakura-jima After-eruption on Jan. 18th, 1914; 6. 34. 04. P. M.

Magnification = 700. (×) Minute Time-cutting. (Photographic enlargement)



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compt.] Prel. tremor lasted 4.1 sec. Max. motion, =0.03 mm., occurred 10.5 sec. after the start. T=0.91 sec.; T=1.56 sec.

	Longit. Compt.	Transv. Compt.
Duration of principal portion, ...	27.5 sec.	26.0 sec
„ spec. active portion, ...	13.7	10.7
Total duration, ...	62.0	53.0

60. *Jan.* 18*th*, 1914; 8.20.44 P.M. A small disturbance, which lasted 21 sec. and 17.7 sec. in the longit. and the transv. components respectively, and then abruptly ended. The definite motion in the longitudinal occurred 3.5 sec. earlier than that in the transverse component.

Longit. compt. .... Max. $2a$=0.018 mm., T=1.57 sec.; T=2.05 sec.
Transv. compt. .... „ =0.015 „ . T=1.95 „ .

61. *Jan.* 19*th*, 1914; 6.50. A.M. This was a fairly large disturbance whose 1st motion was very small and directed toward the origin, and whose 2nd motion was 0.0076 mm. due west, (The diagram has been given in the Bulletin Vol. VIII, No. 1.) The motion became distinct in the transverse component 4.8 sec. later than in the longitudinal. The max. transv. displacement occurred 13.8 sec. after the start.

	Longit. Compt.	Transv. Compt.
Prel. Tremor, ...	Dur.=5.5 sec. $2a$=0.012 mm.	Dur.=6.3 sec. Motion very small.
Dur. of princ. portion, ...	46.5 sec.	40.5 sec.
Dur. of spec. strong part, ...	26.0 „	15.0 „
Total duration, ...	114.0 „	114.0 „
Max. $2a$, ...	0.055 mm.	0.050 mm.
T, ...	1.13 sec.	1.15 sec.

62. *Jan.* 19*th*, 1914; 5.16.38 A.M. The preliminary tremor lasted 4.0 sec. in each component, the 1st displacement being directed away from the Sakura-jima. In the transv. component, the motion was small for 6.8 sec. The max. longit. and the max. transv. displacements occurred respectively 15.2 and 11.3 sec. after the commencement.

	Longit. Compt.	Transv. Compt.
Duration of princ. portion	41. sec.	37 sec.
Total duration, ...	114 ,,	—
Max. 2*a*, ...	0.038 mm.	0.045 mm.
T, ...	0.90 sec.; 1.26 ,,	0.91 sec. 1.10 ,,

63. ***Jan. 19th*, 1914 ; 4.47.00 A.M.** The longit. and the transv. vibrations remained small for the first 8.5 and 6.0 sec. respectively; the motion becoming distinct in the former component 2.6 sec. earlier than in the latter. The longit. motion was most active during the interval of 17.5 to 26.5 sec. from the commencement, max. displacements also occurring 8.5 and 12.0 sec. after the same time moment. The max. transv. epoch set in 14.7 sec. after the commencement, when the longit. motion was at a minimum.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor,......	3.0 sec.	3.5 sec.
,, ,, princ. portion, ...	28.5 ,,	27.5 ,,
,, ,, spec. strong part, ..	21.0 ,,	13.0 ,,
Total duration, ...	100.0 ,,	——
Max. 2*a*, ...	0.05 mm.	0.046 mm.
T, ...	0.91 sec.	0.88 sec. 1.77 ,,

64. ***Jan. 19th*, 1914 ; 7.37.41 A.M.** In the transverse component, the motion remained small for the 1st 8.4 sec., and the max. displacement occurred 10.1 sec. after the commencement.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor, ...	——	3.0 sec.
„ „ princ. portion, ...	42.0 sec.	40.0 „
„ „ spec. strong part, ..	27.5 „	23.0 „
Total duration, ...	67.0 „	67.0 „
Max. $2a$, ...	0.044 mm.	0.042 mm.
T, ...	1.07 sec. 1.03 „	0.86 sec. 1.24 „

65. *Jan. 19th*, 1914; 8.48.36 P.M. There is a doubtful trace of prel. tremor of 5.5 and 2.5 sec. duration in the transv. and longit. components respectively. The moments of the commencement when the motion became distinct were as follows :—

Longitudinal, 8. 48. 36.4 P.M. Transverse, 8. 48. 39.8 P.M.

Thus the longit. motion occurred 3.4 sec. earlier than the transverse. [Longit. compt.] Duration of princ. portion=13.5 sec. Total duration=27 sec. The most active portion, $2a=0.015$ mm., $T=1.25$ sec., occurred 9.4 sec. after the commencement. [Transv. compt.] Princ. portion lasted 14.4 sec., the max. displacement of 0.013 mm. having occurred 5.0 sec. after the commencement. $T=0.86$ sec. After the princ. portion, the motion was practically *nil.*

The elements of motion in some of the other after-eruptions on Jan. 19th are given in Table XVIII.

66. *Jan. 21st*, 1914; 8.44.38 P.M. In the longitudinal direction, the prel. tremor lasted 10.9 sec.: $T=2.4$ sec. The principal portion began simultaneously in the two components, the longit. displacement at the beginning being 0.013 mm. toward the Sakura-jima, corresponding to a complete oscillation in the transv. component composed of the two displacements of 0.005 mm. toward S. 8° W. and of 0.006 mm. toward N. 8° E.

	Longit Compt.	Transv. Compt.
Duration of princ. portion, ...	11.5 sec.	11.0 sec.
Max. 2a, ...	0.029 mm.	0.017 mm.
T, ...	1.2 sec.	1.4 sec. 0.7 ,,

TABLE XVIII. ELEMENTS OF MOTION IN SOME OF THE AFTER-ERUPTIONS OBSERVED ON JAN. 19TH AND 21ST, 1914.

Date (Jan. 1914.)	Time of Occurrence.	Longitudinal Component.				Transverse Component.			
		Duration of		Max. Motion.		Duration of		Max. Motion.	
		Princ. Portion.	Total Disturbance.	2a	T	Princ. Portion.	Total Disturbance.	2a	T
		sec.	sec.	mm.	sec.	sec.	sec.	mm.	sec.
19	2.36.10 A.M.[1]	25.5	69	0.025	1.1	—	—	0.028	0.88 1.7
,,	3.49.57 ,,	22.0	38	0.027	1.02	22.0	—	0.025	1.0
,,	6.05.01 ,,	28.0	80	0.035	1.24	—	—	0.024	1.1
,,	6.31.46 ,, [2]	27.5	75	0.038	1.2	28.0	—	0.038	1.14
,,	8.00.11 ,,	42.5	—	0.038	1.16	31.0	—	0.038	0.80 1.21
,,	8.08.31 ,, [3]	—	—	0.037	0.92 2.6	63.0	97	0.036	0.9 2.5
,,	8.49.26 P.M.	—	—	—	—	—	10.3	0.005	1.6
,,	8.55.32 ,,	—	—	0.01	—	8.8	—	0.011	—
21	3.41.23 A.M[4]	38.0	107	0.05	1.03	34.0	77	0.057	0.83
24	11.29.35 ,,	—	31	0.029	0.9	—	34	0.024	0.58 1.2

(1) Duration of prel. tremor (*longit.*) = 6.2 sec.
(2) ,, ,, ,, ,, (*transv.*) = 14.2 sec.
(3) Duration of specially active part = 18.4 sec. (*longit.*), 17.4 sec. (*transv.*).
(4) ,, ,, ,, ,, ,, = 14.0 sec. ,, 8.1 sec. ,,

67. *Jan. 21st*, 1914; 10.11.53 P.M. The longit. motion began 2.7 sec. earlier than the transverse, and the 1st displacement was 0.006 mm, directed away from the Sakura-jima. [Longit. compt.] For the 1st 6.1 sec., the motion was small and composed of $2\frac{1}{2}$ slow oscillations of $T=2.6$ sec. ($2a=0.018$ mm.) mixed with smaller and quicker movements. For the next 20.8 sec., the motion was larger: $T=2.6$ sec., $2a=0.032$ mm.; $T=1.04$ sec., $2a=0.026$ mm. [Transv. compt.] Motion small for the 1st 5.8 sec.; $T=2.3$ sec., $2a=0.017$ mm.; $T=0.73$ sec. For the next 8.1 sec., the motion was larger, and composed of 4½ vibrations of $T=1.8$ sec., $2a=0.028$ mm. The subsequent motion was much smaller: $T=2.1$ sec., $2a=0.016$ mm.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor and princ. portion,	27.0 sec.	23.0 sec.
Duration of spec. strong part, ...	18.6 ,,	18.7 ,,
Total duration, ...	38.2 ,,	34.5 ,,

68. *Jan. 21st*, 1914; 2.07.26 P.M. The longitudinal motion began 1.0 sec. earlier than the transv. The 1st displacement was 0.032 mm. toward S. 85° W. The first max. motion, which occurred at the commencement of the principal portion of the transverse component, was 0.048 mm. toward N. 58° E. [Longit. compt.] Motion small for the 1st 7.0 sec.: $T=0.78$ sec., $2a=0.017$ mm. For the next 7.5 sec. the motion was most active ($T=0.7$ sec.), beginning with an outward displacement of 0.033 mm. The two max. movements of 0.037 mm. and 0.046 mm. occurred respectively 9.9 sec. and 14.2 sec. after the commencement. Thereafter the period was $T=0.8$ sec. ($2a=0.026$ mm.). At the end, the motion was slow: $T=1.25$ sec. [Transv. compt.] Motion small for the 1st 4.3 sec.: $T=0.61$ sec., $2a=0.01$ mm. For the next 4.4 sec., the motion was a little larger: $T=0.73$ sec., $2a=0.016$ mm. Then there followed for 2.0 sec. the most active part: $T=0.67$ sec., $2a=0.043$ mm. Thereafter slow movements of $T=1.27$ sec. were mixed with those of $T=0.66$ sec. ($2a=0.031$ mm.).

	Longit. Compt.	Transv. Compt.
Duration of princ. portion, ...	31.0 sec.	25.4 sec.
,, ,, spec. strong part, ...	17.7 ,,	12.2 ,,
Total duration, ...	66.0 ,,	55.0 ,,

69. *Jan. 22nd*, 1914; 2.54.18 A.M. This was a fairly large disturbance, of the total duration of 76 sec. The princ. portion lasted 47 and 44 sec. respectively in the longit. and the transv. components. The very 1st displacement was small and directed toward Sakura-jima, while the 2nd was 0.013 mm. toward N. 54° W. The most active part, which lasted 22 sec., began 6.5 sec. later on, commencing with the longit. displacement of 0.045 mm. toward Sakura-jima, accompanied by two transv. displacements of 0.015 mm. toward N. 8° E. and of 0.013 mm. toward S. 8° W. The max. vibration, which occurred 16.5 sec. after the start, was as follows: $2a=0.047$ mm. toward N. 28°½ W., $2a=0.055$ mm. toward S. 48°½ E. In the transv. component, $T=1.18$ sec., $T=2.24$ sec.

70. *Jan. 22nd*, 1914; 9.38.45 A.M. Total duration = 64 sec.; duration of princ. portion=38 sec. The 1st displacement (=0.01 mm.) in the longit. component occurred 1.3 sec. earlier than in the transverse, and was directed away from Sakura-jima. Max. displacement in each component was 0.037 mm. (slow motion), and 0.02 mm. (quick motion).

71. *Jan. 22nd*, 1914; 10.45.20 A.M. Total duration =32.3 sec. The 1st displacement (=0.013 mm.) in the longit. component occurred 2.2 sec. earlier than in the transverse, and directed away from Sakura-jima.

Longit. Max. $2a=0.025$ mm., $T=1.04$ sec., $T=1.16$ sec.
Transv. ,, $=0.023$,, , $T=1.02$ sec., $T=0.75$ sec.

72. *Jan. 22nd*, 1914; 11.44.43 A.M. The 1st displacement was 0.011 mm. toward S. 70° W. The motion became well pronounced 4.0 sec. earlier in the longit. than in the transv. component.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor, ...	— sec.	4.0 sec.
,, princ. portion, ...	26.5 ,,	22.0 ,,

Total duration, ...	51.0 sec.	—
Max. $2a$, ...	0.028 mm.	0.024 mm.
T, ...	0.77 sec.	0.77 sec.

73. *Jan. 22nd,* 1914; 1.10.28 P.M. Definite movements occurred 2.5 sec. earlier in the longit. than in the transv. component.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor, ...	—	4.4 sec.
,, princ. portion, ...	36.5 sec.	28.2 ,,
Total duration, ...	57.5 ,,	47.3 ,,
Max. $2a$, ...	0.023 mm.	0.024 mm.
T, ...	0.85 sec.	—

74. *Jan. 22nd,* 1914; 7.47.50 P M. This was a very small disturbance composed of slow movements, and was due to an outburst whose loud detonation was perceived in Kagoshima (at the Satsumaya Hotel) at about 7.47.50 P.M. The 1st definite motion occurred 2.8 sec. earlier in the longit. than in the transv. component. Total duration =32 sec. [Longit. compt.] The princ. portion appeared 5.4 sec. after the commencement: max. $2a=0.012$ mm., $T=1.9$ sec. [Transv. compt.] Max. $2a=0.008$ mm., $T=1.8$ sec.

75. *Jan. 23rd,* 1914; 2.20.20 A.M. Also a small and very slow disturbance, due to an outburst whose loud booming sound was perceived in Kagoshima at 2.20.37 A.M. The longit. motion occurred 7.0 sec. earlier than the transverse, the 1st displacement being 0.0015 mm. toward, and the 2nd 0.006 mm. away from Sakura-jima. [Longit. compt.] Total duration =45.5 sec. Motion small for the 1st 8.0 sec. The princ. portion lasted 15.0 sec.: $T=$ 1.9 sec., $2a=0.014$ mm.; $T=1.28$ sec., $2a=0.012$ mm. [Transv. compt.] Total duration=27 sec., no prel. tremor being indicated. The princ. portion lasted 16 sec. and was nearly uniform: $T=2.0$ sec., $2a=0.014$ mm.; $T=0.68$ sec.

76. *Jan. 24th*, 1914; 6.28.43 P.M. The 1st distinct displacement was 0.006 mm. toward S. 48° E.

	Longit. Compt.	Transv. Compt.
Duration of princ. portion,	32.7 sec.	19.8 sec.
Total duration,	—	67.0 ,,
Max. 2a,	0.023 mm.	0.027 mm.
T,	0.91 sec.	0.73 sec.; 1.2 sec.

77. *Jan. 24th*, 1914; 3.28.54 P.M. [Prel. tremor.] The 1st motion was directed away from Sakura-jima, and=0.009 mm., accompanied by a transverse vibration composed of two displacements of 0.002 mm. toward N. 8° E. and of 0.002 mm. toward S. 8° W. *Longit.*: $T=0.94$ sec., $2a=0.009$ mm. *Transv.*: $T=0.73$ sec., $2a=0.005$ mm. [Princ. portion.] The 1st displacement was 0.02 mm. toward N. 60° E. *Longit.*: duration=21.8 sec., $T=1.04$ sec. *Transv.*, duration=22.2 sec., $T=0.89$ sec.

78. *Jan. 26th*, 1914; 11.18.57 P.M. Total duration = 43 sec., duration of princ. portion=23 sec. *Longit.*: $T=0.9$ sec., $2a=0.017$ mm. *Transv.*: $T=0.8$ sec., $2a=0.023$ mm.

79. *Jan. 26th*, 1914; 2.41.04 A.M. Total duration =69 sec.; duration of princ. portion=27.5 sec. Definite motion in the longit. occurred 5.0 sec. earlier than in the transv. component, *Longit.*, $T=0.97$ sec., $2a=0.024$ mm.; *transv.*, $T=0.91$ sec., $2a=0.022$ mm.

80. *Jan. 26th*, 1914; 3.46.59 A.M. Total duration =68 sec.; duration of princ. portion=24 sec. The well defined princ. portion began 6.5 sec. earlier in the longit. than in the transv. component, the 1st displacement of this stage being 0.015 mm. toward S. 88°W. The max. longit. motion of 0.034 mm. occurred 17.5 sec. after the commencement of the princ. portion. *Longit.*, $T=1.33$ sec,, $2a=0.034$ mm.; *transv.*, $T=1.35$ sec., $2a=0.031$ mm.

81. *Jan. 26th*, 1914; 6.01.33 A.M. Total duration=54 sec.; duration of the prel. tremor=9.0 sec. The princ. portion in the longit. occurred 4.9 sec. earlier than that in the transv. component. *Longit.*, $T=1.03$ sec., $2a=0.019$ mm.; *transv.*, $T=1.03$ sec., $2a=0.024$ mm.

82. *Jan. 26th*, 1914; 9.00.09 A.M. The disturbance was very small and slow and was due to an outburst which caused a strong detonation with shaking effects perceived in Kagoshima (at the Satsumaya Hotel) at 9.01.01 A.M.

	Longit. Compt.	Transv. Compt.
Duration of princ. portion, ...	48.5 sec.	46.5 sec.
Total duration, ...	over 88. ,,	91. ,,
Time of commencement, ...	9.00.09 A.M.	9.00.09 A.M.
Motion slightly increased at	9.00.17	9.00.15½
,, became definite at	9.00.23,6	9.00.29,4
Maximum portion began at	9.00.34,8	9.00.40,3
,, ended at	9.01.18,6	9.01.26,8

[Longit. compt.] During the 1st 31 sec. of the princ. portion, $T=2.4$ sec., $2a=0.016$ mm. Thereafter, $T=1.26$ sec., $2a=0.019$ mm. [Transv. compt.] $T=2.6$ sec.; $T=1.4$ sec., $2a=0.012$ mm.; $T=0.66$ sec.

83. *Jan. 29th*, 1914; 10.51.03 P.M. The motion became definite in the transv. component 2.6 sec. later than in the longit. The very 1st quick displacement was 0.013 mm. directed away from Sakura-jima, while the two slow vibrations at the commencement were composed of the following displacements:—

1st Slow Vibration	1st displt., ...	0.015 mm., toward	due west.
	2nd ,, ...	0.018 ,, , ,,	due east.
2nd Slow ,,	1st ,, ...	0.032 ,, , ,,	S. 55°W.
	2nd (max.)	0.033 ,, , ,,	N. 70°E.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor, ...	3.3 sec.	—
,, princ. portion, ...	24.7 ,,	19.7 sec.
Total duration, ...	35.0 ,,	—

Quick vibration	T,	0.94 sec.	0.92 sec.
	Max. $2a$,	0.024 mm.	0.019 mm.
Slow vibration, T,		2.1 sec.	1.9 sec.

84. *Photographic enlargements.* In §§ 85 to 89 are given the results of analysis of the photographically enlarged copies of the diagrams of the following 5 after-eruptions :—

Jan. 17th, 1914 ; 10.41.58½ P.M.
„ 18th, „ ; 6.07.42 „
„ ; 6.34.04 „
„ ; 7.15.40 „
„ 21st, „ ; 2.19.57 „

The motion consisted of slow vibrations, as was the case with the shakings of the ground caused by the Asama-yama explosions. (See the Bulletin, Vols. VI and VII.) Illustrative diagrams are reproduced in figs. 15 to 21 (Pls. LXXIX to LXXXV).

85. *Jan. 17th,* 1914 ; 10.41.58½ P.M. This was due to an outburst from one of the W. side craterlets, whose strong detonation was perceived by the author at 10.42.13 P.M. at the Satsumaya Hotel in Kagoshima.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor and princ. portion,	16.8 sec.	21.2 sec.
Duration of most active part,	—	11.0
Total duration,	68.	60.

The very first displacement was directed radially outwards from Sakura-jima, and the transverse component was nearly zero during the first 1.5 sec. [Longit. compt.] For the first 2.5 sec. : $T=$ 1.01 sec., $2a=0.016$ mm. For the next 6.5 sec., the motion was comparatively slow : $T=2.15$ sec., $2a=0.018$ mm. Then, for 7.8 sec., the motion was most active and regular ($T=1.2$ sec.) and indicated the following two maximum movements at the commencement and the end :—

1st Displacement 0.032 mm., toward S. 40°E.
Last ,, 0.028 ,, , ,, S. 86°E.

This portion was essentially longitudinal in character, but for the next 4.4 sec., the longitudinal component was nearly zero. Then at 21.2 sec. after the start, there occurred a well pronounced displacement of 0.020 mm., toward N. 82°E. The subsequent motion was much smaller, there being 6.3 sec. later on a few vibrations of $T=1.06$ sec., $2a=0.01$ mm. [Transv. compt.] During the first 5.7 sec., the motion was small: $T=0.76$ sec., $2a=0.011$ mm. Then there took place a prominent vibration of $T=0.96$ sec., and $2a=0.020$ mm., which was purely transverse; the corresponding longitudinal component being zero. The motion continued quick in period for the next 4.9 sec.: $T=1.10$ sec., ($2a=0.022$ mm.). For the next 14.7 sec., the motion was large, but slow: $T=2.1$ sec., $2a=0.021$ mm. Thereafter the vibrations were abruptly reduced and remained nearly uniform for 16 sec.: $T=2.1$ sec., $2a=0.01$ mm. The subsequent motion was very small.

86. *Jan. 18th*, 1914; 6.07.42 P.M. (Fig. 19.) The very first displacement was 0.0013 mm. directed outward from, and the 2nd was 0.0043 mm. toward to, the Sakura-jima radially, the commencement of the longitudinal motion being 2.0 sec. earlier than that of the transverse.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor,	3.2 sec.	— se
,, princ. portion,	38.5 ,,	32.5 ,,
,, most active part,	20.6 ,,	16.1 ,,
Total duration,	98. ,,	87. ,,

The movements during the successive stages were as follows :—

<table>
<tr><th>Longitudinal Component.</th><th>Transverse Component.</th></tr>
<tr><td colspan="2">(i). Preliminary Tremor : Duration = 3.2 sec.</td></tr>
<tr><td>Motion small and composed of two slow vibrations of $T=1.58$ sec., $2a=0.0072$ mm.</td><td>Motion very small : $T=0.9$ sec.</td></tr>
<tr><td colspan="2">(ii). 8.4 sec.</td></tr>
<tr><td>Slow movements : $T=1.05$ sec., $2a=0.044$ mm.</td><td>Quick vibrations : $T=0.84$ sec., $2a=0.014$ mm.</td></tr>
<tr><td colspan="2">(iii). 3.8 sec. : Motion essentially transverse.</td></tr>
<tr><td>Motion small : $T=0.93$ sec., $2a=0.019$ mm.</td><td>$T=1.10$ sec. The 1st vibration was a maximum, and composed of the two displacements of 0.022 mm. and 0.047 mm. directed toward S. 8° W. and N. 8° E. respectively ; the simultaneous longit. component being zero.</td></tr>
<tr><td colspan="2">(iv). 8.6 sec. : Motion most active and regular.
$T=1.2$ sec. The 1st vibration was a maximum and composed of the following two displacements :—
{1st Displacement 0.061 mm., toward N. 34°W.
{2nd ,, 0.062 ,, ,, S. 46°E.
The 1st displacement of the last but one vibration, which occurred 2[illegible]4 sec. after the start, was the absolute maximum : 0.067 mm. toward N. 75°W.</td></tr>
<tr><td colspan="2">(v). 23.5 sec. : Motion small.</td></tr>
<tr><td>$T=1.13$ sec., $2a=0.023$ mm.</td><td>$T=1.19$ sec., $2a=0.019$ mm.</td></tr>
<tr><td colspan="2">The subsequent motion was very small.</td></tr>
</table>

87. *Jan. 18th,* 1914; 6.34.04 P.M. (Fig. 21.) The very 1st two quick displacements were entirely longitudinal, and respectively 0.007 mm. outward from, and 0.015 mm. toward the Sakura-jima. The transverse component became distinct 3.0 sec. later than the longitudinal.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor, ...	3.6 sec.	3.6 sec.
,, princ. portion, ...	44. ,,	37. ,,
,, specially strong part, ...	30. ,,	22. ,,
Total duration, ...	99. ,,	——

Longitudinal Component.	Transverse Component.
(i). Prel. Tremor: Duration $=3.6$ sec.	
$T=0.89$ sec., $2a=0.015$ mm. Slow vibr., $2a=0.027$,,	$T=0.74$ sec., $2a=0.0035$ mm.
(ii). 7.6 sec.	
$T=2.24$ sec., $2a=0.045$ mm.	Motion uniform and composed of 3 vibrations of $T=2.35$ sec., $2a=0.022$ mm. $T=0.78$ sec., $2a=0.013$ mm.
(iii) Max. Transverse Stage: Duration $=9.1$ sec.	
Motion regular: $T=1.32$ sec., $2a=0.039$ mm.	Begins with the absolute max. $2a=0.06$ mm. directed toward S. 8° W., the simultaneous longit. component being zero. $T=1.14$ sec.
(iv). Active Longitudinal Stage: Duration $=5.6$ sec.	
Motion regular: $T=1.24$ sec.	Motion small: $T=1.49$ sec., $2a=0.03$ mm.

The three successive displacements at the commencement of this portion were as follows :—

1st Displacement = 0.052 mm., toward S. 36°E.
2nd ,, = 0.051 ,, , ,, N. 66°W.
4th ,, = 0.052 ,, , ,, N. 82°W.

(v). 17.8 sec. : Motion smaller.

$T=0.93$ sec., $2a=0.021$ mm.	$T=1.11$ sec., $2a=0.018$ mm.

(vi). Motion very small.

	$T=1.7$ sec.

88. *Jan. 18th*, 1914 ; 7.15.40 P.M. (Fig. 20.) Total duration = 48 sec.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor, ...	6.5 sec.	10.7 sec.
,, princ. portion, ...	24.0 ,,	18.4 ,,

Longitudinal Component.	Transverse Component.

(i). 10.7 sec.

$T=1.01$ sec., $2a=0.034$ mm.	$T=0.74$ sec., $2a=0.012$ mm.

(ii). 5.7 sec.

Begins with the absolute max. displacement : 0.051 mm. toward Sakura-jima, corresponding to	Begins with a max. vibration of the two displacements :— 1st displ. = 0.034 mm., toward N. 8°E. 2nd displ. = 0.027 mm., toward S. 8°W. The slow absolute max. vibr. occurred 13.0 sec. after the start :—

Longit. motion=0	1st displ.=0.042 mm.,→S.8°W.
,, =0.043mm. outward	2nd displ.=0.043 mm.,→N.8°E.

The latter gives the resultant motion of

$2a$=0.061 mm., toward N. 30°W.

T=1.15 sec.	T=1.64 sec.; T=0.82 sec.

(iii). 14.3 sec.

Motion regular and began with a max. vibration:—

1st Displacement=0.035 mm., toward S. 57°E.

2nd ,, =0.046 ,, , ,, N. 59°W.

T=1.13 sec.	T=1.36 sec.

The subsequent motion was small.

89. *Jan. 21st*, 1914; 2.19.57 P.M. (Fig. 16.) The very first displacement was 0.0013 mm., directed toward N. 77°E. The disturbance lasted 49 sec. and then ended abruptly.

	Longit. Compt.	Transv. Compt.
Dur. of prel. tremor, ...	1.9 sec.	3.8 sec.
,, princ. portion, ...	31.7 ,,	27.5 ,,
,, specially strong part, ...	12.8 ,,	12.0 ,,

Longitudinal Component.	Transverse Component.

(i). 1st 7.5 sec.

Motion small and slow:—	Motion small, but distinct:—
T=1.01 sec., $2a$=0.026 mm.	T=0.72 sec., $2a$=0.013 mm. T=1.28 ,, , $2a$=0.015 ,,

(ii). 63 sec.

Motion was well-defined in both components, but more active in the transverse than in the longitudinal direction. The first vibration was entirely transverse and composed of the two displacements: 1st, 0.013 mm. toward S. 5°W.; 2nd, 0.011 mm. toward N.5°E. The next displacement was 0.023 mm. toward S.36°W. The 2nd displacement of the 4th (transverse) vibration, occurring 10.4 sec. after the start, was the greatest transverse motion, of $2a=0.041$ mm. This combined to the outward (longit.) displacement of 0.024 mm. gives the resultant of 0.047 mm. toward N.22°W.

(iii), Longit. Motion Stage: Duration=8.3 sec.

Motion regular:	Motion irregular and slow:
$T=0.83$ sec.	$T=1.32$ sec.; $T=0.52$ sec.

1st Displacement 0.035 mm. toward N.38°W.
2nd ,, 0.038 ,, . ,, S.62°E.

The 1st displt. of the last vibration, occurring 20.8 sec. after the start, was the 2nd max. in this stage: $2a=0.029$ mm. toward S.74°E.

(iv) Last 11.8 sec.: Motion small and uniform.

$T=1.10$ sec., $2a=0.017$ mm.	$T=1.57$ sec., $2a=0.012$ mm. $T=0.78$,, , $2a=0.012$,,

---

90. *Duration of the preliminary portion.* The duration of the introductory small motion in the diagrams of the different after-eruptions was as follows:—

Longitudinal Component. sec.		Transverse Component. sec.	
1.9		2.8	
2.5		3.0	
2.5		3.5	
2.8		3.6	
3.0	Mean,	3.8	Mean,
3.2	3.6 sec.	4.0	4.8 sec.
3.6		4.1	
4.0		4.3	
4.1		5.5	
5.5		5.7	
6.5		6.3	
		10.7	

The mean duration of the preliminary portion (=3.6 sec.) in the longitudinal component was about 2.0 sec. longer than the duration of the ordinary *preliminary tremor* (=1.6 sec.) corresponding to the distance of 11.8 km. between the place of observation and the craterlet No. 2 on the eastern, or Nabe-yama, side of Sakura-jima, which was most active in the days in question. This time difference may be assumed to indicate the duration of the preparatory stage of the after-eruptions. In the transverse component, the mean duration of the preliminary portion was 4.8 sec., being 1.2 sec. longer than in the longitudinal component.

91. ***Range of motion.*** The maximum range of motion, or double amplitude $=2a$, in either the longitudinal or the transverse component of the after-eruption movements on the successive days was as follows:—

Date.	Absolute maximum, $2a$
Jan. 16th	0.054 mm.
17th	0.048
18th	0.062
19th	0.055
21st	0.046
22nd	0.055
23rd—24th	0.029
25th—26th	0.034
29th	0.032

Thus, between the 16th and the 22nd the max. $2a$ was nearly constant and approximately equal to 0.05 mm. Between the 23rd and the 29th, it was smaller and about 0.03 mm.

92. ***Difference in times of arrival of longitudinal and transverse vibrations.*** Distinct motion in the transverse component occurred, on the average, 3.9 sec. $(=\tau)$ later than that in the longitudinal component, as follows:—

τ=2.5 sec.	3.5 sec.
2.6	4.0
2.6	4.5
2.7	4.8
2.8	4.9
3.0	5.0
3.4	6.2
	6.5
	3.9 sec.

93. ***Time of occurrence of maximum movements.*** In the earthquake motion due to an after-eruption observed in Kagoshima, the principal values of the average time interval between the com-

TABLE XIX. TROMOMETER OBSERVATION IN KAGOSHIMA: TIME INTERVAL BETWEEN THE COMMENCEMENT AND THE OCCURRENCE OF THE MAXIMUM VIBRATION OR THE MOST ACTIVE PORTION OF THE EARTHQUAKE MOTION DUE TO THE AFTER-ERUPTIONS.

Longitudinal Component.				Transverse Component.			
sec.		sec.		sec.		sec.	
5.4	Mean, 8.2	13.8	Mean, 15.8	8.4	Mean, 11.0	6.0	Mean, 6.2
6.3		14.2		8.7		6.3	
6.4		15.2		9.7			
7.0		15.4		10.1		13.0	Mean, 13.8
7.1		16.4		10.4		13.8	
8.0		16.5		10.5		14.7	
8.5		17.5		10.5			
9.0		17.5		10.6			
9.4		20.3	Mean, 21	10.9			
9.9		20.8		11.2			
10.7		21.4		11.3			
10.9		21.4		11.6			

mencement and the maximum vibration or the most active portion, were, according to Table XIX, as follows:—

Longit. Compt.,	8.2 sec.; 15.8 sec.
Transv. Compt.,	11.0 ,,

Thus the 1st maximum motion occurred generally 11.0–8.2=2.8 sec. earlier in the longitudinal than in the transverse component. In the longitudinal component, the 1st maximum occurring 8.2 sec. after the commencement was often followed by a 2nd maximum about 8 sec. later on.

94. *Direction of motion.* The 1st distinct displacement in the earthquake motion due to the Sakura-jima after-eruptions was directed mostly toward to, or away from, the source of disturbance. Thus, of the 20 cases examined, the direction of the initial motion was as follows:—

Toward the source of disturbance,	5 cases;
Away from ,, ,, ,	11 ,, ;
Toward N. 77° E.; S. 47° E.; S. 70° W.; S. 48° E.,	each, 1 case.

It is possible that, in some instances, the initial displacement was obliterated by the small tremors of the ground existing more or less in the days subsequent to the commencement of the eruption.

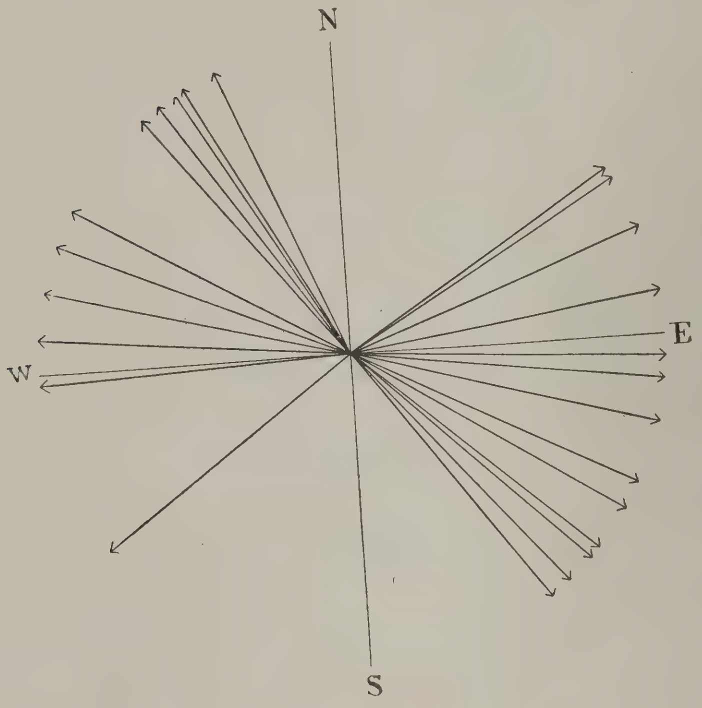
The mean directions of the maximum displacements in the principal portion were, according to Table XX, as follows:—

Longitudinal Component,	N. 70° W.—S. 70° E.
Transverse ,, ,	N. 10° E.—S. 10° W.

These directions are approximately parallel and normal to the straight line connecting the craterlets on the two flanks of the volcano.

Fig. 22. Tromometer Observation in Kagoshima of the Sakura-jima After-eruptions: Direction of the Maximum Vibration.

(Different After-eruptions taken together)



35. ***Period of vibration.*** Tables XXI and XXII give lists of the vibration periods in the earthquake motion caused by the different after-eruptions. The mean values of the periods most frequently occurring in the maximum phase of the longitudinal component were $p_1=1.09$ sec. and $p_2=2.22$ sec. The period p_1, which is equal to $\frac{1}{2}\times p_2$, was often found also in the parts preceding and following the maximum phase of the longitudinal component and in the maximum phase of the transverse component. Other periods frequently occurring in the latter motion were 0.71 sec. and 1.39 to 1.7 sec.

TABLE XX. TROMOMETER OBSERVATION OF THE SAKURA-JIMA AFTER-ERUPTIONS IN KAGOSHIMA, JAN. 16TH—FEB. 8TH, 1914: DIRECTION OF THE MAXIMUM MOVEMENTS IN THE PRINCIPAL PORTION.

Longitudinal Motion.		Transverse Motion.	
N. 22° W.	S. 36° E.	N. 5° E.	S. 5° W.
N 28°½W.	S. 40° E.	N. 8° E.	S. 8. W.
N. 30° W.	S. 40° E.	N. 8° E.	S 8° W.
N. 34° W.	S. 48°½E.		S. 8° W.
N. 38° W.	S. 57° E.		S. 8° W.
N. 59° W.	S. 62° E.		S. 36° W.
N. 66° W.	S. 74° E.	(ii) **N. 10°E.—S. 10°W.**	
N. 75° W.	S. 82° E.		
N. 82° W.	S. 86° E.		
W.	E.		
S. 88° W.	N. 82° E.		
S. 55° W.	N. 70° E.		
	N. 60° E.		
	N. 58° E.		
(i) **N. 70°W.—S. 70°E.**			

	Longit. Compt.			Transv. Compt.		
	sec.	sec.	sec.	sec.	sec.	sec.
Max. phase.............	**1.09** ;	1.55 ;	**2.22**	**1.00** ;	**1.7** ;	2.4
Parts preceding and following the max. phase,..	**0.99** ;	1.58 ;	2.4	**0.71** ;	**1.39** ;	2.3

(The frequently occurring periods are printed in thick characters.)

Comparison with the Asama-yama and the Usu-san observations. The mean values of the periods occurring in the earthquake motion caused by the recent Asama-yama eruptions tromometrically observed at several observing stations on the mountain slope and base, at the distance of 2.3 to 6.35 km. from the centre of the crater, were as follows*:—

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* See the Bulletin, Vol. VII, No. 1.

TABLE XXI. AFTER-ERUPTIONS OBSERVED IN KAGOSHIMA: PERIOD OF VIBRATION.

(Directly measured from the original tromometer diagrams.)

Longitudinal Component.			Transverse Component.		
Max. Phase.		Parts preceding and following the Max. Phase.	Max. Phase.		Parts preceding and following the Max. Phase.
0.70 sec.	1.52 sec.	0.60 sec.	0.57 sec.	1.35 sec.	0.44 sec.
0.77	1.57	0.78	0.58	1.40	0.61
0.85	1.55	0.80	0.66	1.40	0.66
0.90		0.90	0.67	1.56	0.73
0.90	1.90	0.94	0.68	1.60	0.73
0.90	1.90	1.20	0.70	1.70	0.73
0.91	2.05	1.25	0.73	1.77	0.88
0.91	2.10	0.92	0.75	1.80	0.68
0.92	2.40		0.77	1.80	
0.94	2.60	2.50	0.80	1.80	1.27
0.97	2.60	2.60	0.80	1.90	1.40
1.02	2.22	2.55	0.83	1.95	1.3
1.03			0.86	2.00	
1.03			0.86	1.7	2.1
1.03			0.88		2.3
1.03			0.88	2.24	2.4
1.04			0.89	2.50	2.3
1.04			0.90	2.60	
1.04			0.91	2.4	
1.07			0.91		
1.10			0.91		
1.11			0.92		
1.13			0.98		
1.16			1.00		
1.16			1.00		
1.20			1.02		
1.20			1.03		
1.24			1.10		
1.25			1.10		
1.26			1.14		
1.26			1.15		
1.28			1.18		
1.30			1.20		
1.33			1.20		
1.06			1.21		
			1.24		
			0.92		

(a)	4.9 sec.	(d)	0.85 sec.
(b)	2.3 „	(e)	0.37 „
(c)	1.25		

Of the five groups the most frequently occurring period were (d) and (c), and then (b). Again, the mean values of the periods existing in the micro-tremor motion observed at the time of the Usu-san eruption, July–Aug., 1910, in the immediate vicinity of the craterlets, were four-fold as follows* :—

(b′)	2.14 sec.	(d′)	1.08 sec.
(c′)	1.59 „	(e′)	0.53 „

TABLE XXII. AFTER-ERUPTIONS OBSERVED IN KAGOSHIMA: PERIOD OF VIBRATION.

(Measured from the photographic enlargements)

Longitudinal Component.			Transverse Component.		
Max. Phase.	Parts preceding and following the Max. Phase.		Max. Phase.	Parts preceding and following the Max. Phase.	
0.83 sec.	0.89 sec.	1.58 sec.	0.96 sec.	0.52 sec.	1.11 sec.
1.13	0.93		1 10	0.72	1.19
1.20	0.93	2.15	1.10	0.74	1.28
1.20	1.01	2.24	1.14	0.74	1.36
1 24	1.01	2.2	1.08	0.76	1.49
1.12	1.01			0.78	1.59
	1.05		1.64	0.78	1.70
	1 06		2.1	0.84	1.39
	1.10		1.9	0.90	
	1.13			0.75	2.10
	1.15				2.35
	1.32				2.2
	1.05				

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* See the Bulletin, Vol. V, No. 1.

b′, c′, d′, and e′ are not widely different respectively from the periods b, c, d, and e, characterizing the Asama-yama eruptions.

The periods prevailing in the motion of the Sakura-jima after-eruptions observed in Kagoshima were approximately equal to those found at the Asama-yama and Usu-san. In the case of the observations at the two latter places, the vibration periods in the eruptive earthquakes and in the volcanic micro-tremors were found to be essentially identical with the slower periods existing in the motion of ordinary earthquakes. A similar relation seems to exist also in the Kagoshima observations.

CHAPTER VI. TROMOMETER OBSERVATION AT FRUSATO OF THE SAKURA-JIMA AFTER-ERUPTIONS.

96. *Tromometer observation at Frusato.* The portable horizontal pendulum tromometer, of the pointer magnification =200, used in Kagoshima since Jan. 16th, 1914, (§ 30), was taken on Feb. 9th to Sakura-jima and set up at the village of Frusato, 3.8 km. to the S. 45° W. from the centre of the craterlet-zone on the S.E. side of the volcano. The two horizontal pointers of the tromometer were oriented so as to register respectively the motion radial and the motion transverse to the mean origin of the disturbance; the proper pendulum period being 4.5 sec. for each component.

The first series of the tromometer observation at Frusato extended for 112 days from Feb. 9th to May 31st, 1914. The lower craterlets on the S.E., or Nabe-yama, side maintained active outbursts for the several succeeding months; causing in the Autumn next, amongst the others, a serious damage to the rice crop in the vicinity of Kagoshima. At the request of the governor of the

Kagoshima prefecture, who was anxious to know the probable course of the variation in the amount of the precipitation of the injurious ashes, the tromometer observation at Frusato was resumed on Oct. 24th, 1914 and continued for the 79 days till January 10th, 1915; the object being to determine the rate with which the after-eruptions decreased in frequency and intensity. The work of the observation was carried on by my assistant, Mr. H. Krosaka, and by Messres. Atsumi, Ando, Matsuda, and Hirase, of the Kagoshima meteorological observatory. Tables XXV and XXVI give the daily numbers of the after-eruptions and earthquakes registered at Frusato during the two series of the observation.

97. ***Daily frequency of "larger"* after-eruptions.*** The daily number of the "larger" disturbances was 124 on Feb. 10th; 87 to 50, with the mean of 71, between the 11th and the 13th; 22 to 16, with the mean of 19.3, between the 14th and the 16th; and 13 to 5, with the mean of 7.3, between the 17th and the 26th; being in the subsequent days much smaller and less than 4, except on March 8th and 29th, whose frequency were respectively 9 and 5.

The marked decrease in the frequency on and after the 14th (February) might be due partly to the occurrence of the Iwo-jima earthquake on the preceding day, the 13th; just in the same way as the recent explosive activity of the Kirishima-yama, Nov. 1913 to Jan. 8th, 1914, was brought to an end by the last great eruption of the Sakura-jima.

The frequent occurrence of the "larger" after-eruptions ended in the Kagoshima observation with Jan. 27th, and in the Frusato observation practically with Feb. 16th, or respectively 15 and 35 days after the commencement of the eruptions on Jan. 12th, corresponding probably to the marked reduction of the eruptive activity of the western, or Yokoyama, side and the eastern, or Nabe-yama, side craterlet groups.

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* For the definition of *large* and *small disturbances*, see the Bulletin, Vol. VIII, p. 26.

98. Comparison of frequencies of larger after-eruptions registered at Kagoshima and Frusato. In the following list are given the 2–daily numbers of the larger after-eruptions tromometrically registered at Kagoshima and Frusato.

Kagoshima.

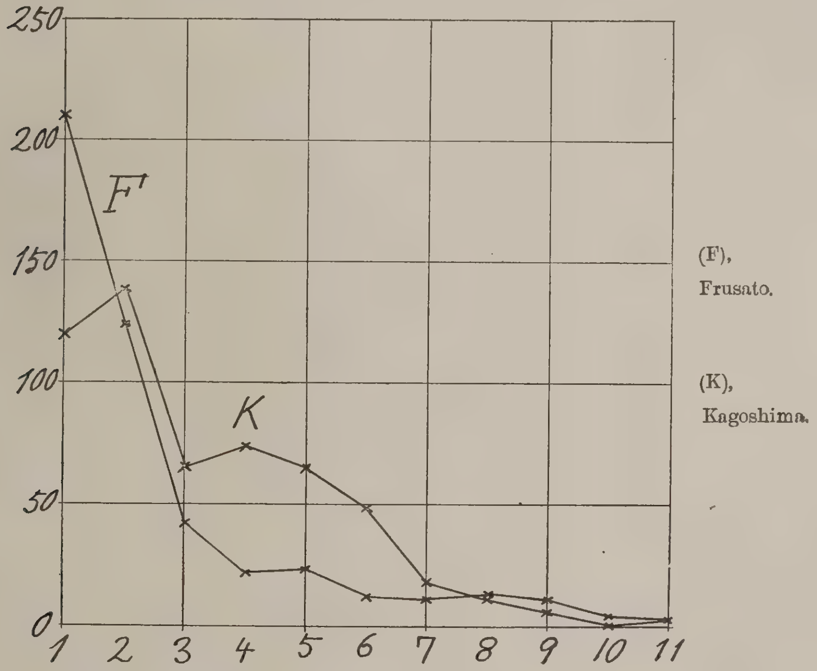
	Days.	Number of Eruptions.
Jan.	17–18	120
	19–20	139
	21–22	66
	23–24	74
	25–26	65
	27–28	49
	29–30	18
	31–Feb. 1	11
Feb.	2–3	6
	4–5	0
	6–7	3

Frusato.

	Days.	Number of Eruptions.
Feb.	10–11	211
	12–13	124
	14–15	42
	16–17	22
	18–19	23
	20–21	12
	22–23	11
	24–25	13
	26–27	11
	28–March 1	4
March	2– 3	3
	4– 5	1
	6– 7	5
	8– 9	13
	10–11	4
	12–13	2
	14–15	0
	16–17	0
	18–19	1
	20–21	3
	22–23	2
	24–25	8
	26–27	4
	28–29	5
	30–31	1

In Kagoshima, the two-daily frequency decreased from 120 or 139 to 49 in the course of about 10 or 11 days between 17th–18th to 27th–28th in January, while at Frusato it decreased from 211 to 42 in the course of only about 5 days between 10th–11th to 14th–15th in February.

Fig. 24. Comparison of the 2-daily After-eruption Frequency at Frusato with that at Kagoshima.



The numerals 1, 2, 3....on the abscissa axis correspond to the successive 2-days intervals in the list on p. 442.

As graphically shown in fig. 23, the time relation of the frequency of the after-eruptions was not quite regular in the Kagoshima observation, which was made between Jan. 16th and Feb. 8th. This might be due to the fact that in the case under consideration the tremor-recorder registered the eruptions from the western, or Yokoyama, side group of the craterlets as well as those from the eastern, or Nabe-yama side, craterlets. As the two different eruption centres exhibited maximum activity at different, and probably alternating, moments, the variation of the total eruption frequency would naturally be not one of a simple decrease. On the other hand, in the case of the Frusato observations, made since Feb. 9th, the eruptions registered were entirely those originating from the Nabe-yama side craterlets, quite close to the seismograph station, the craterlets on the west end of the island having then already been reduced to rest. Consequently the time relation of the eruption frequency found at Frusato was quite simple, being approximately one of rectangular hyperbola.

99. *Decrease rate of the frequency of larger after-eruptions.*

The relation between the time (x) and the daily frequency (y) of the "larger volcanic disturbances" for the earlier portion of the observations at Frusato can very nearly be represented by the equation

$$\log y = 2.09962 - 0.14187\,x, \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

in which $x=0$ denotes the 10th of Feb., 1914. The actual and calculated values of the frequency for $x=0$ to 9 are indicated in the following table :—

Date (Feb. 1914)		Actual.		Calculated (Equation 1).
10th	$x=0$	$y=124$		$y=126$
11th	1	87		91
12th	2	74		65
13th	3	50		47
14th	4	22	Mean, 19.3	25
15th	5	20		
16th	6	16		
17th	7	6	Mean, 9.7	9
18th	8	10		
19th	9	13		

If we, however, consider the variation of the number ($=y$) of the eruptions during the successive 10–day intervals ($=x$ whose 0 corresponds to Feb. 10th to 19th, 1914), the rectangular hyperbola equation

$$y=\frac{56.77}{x+0.137} \quad \dotfill \quad (2)$$

is found to express the mutual relation with a fair accuracy, as follows :—

x	10–Days Interval. (1914.)	y, actual.		y, calculated.
0	Feb. 10th–Feb. 19th.	422		415
1	„ 20th–March 1st.	51		50
2	March 2nd– „ 11th.	26	Mean, 17.3	18.1
3	„ 12th– „ 21st.	6		
4	„ 22nd– „ 31st.	20		
5	April 1st–April 10th.	9	Mean, 9.3	9.2
6	„ 11th– „ 20th.	12		
7	„ 21st– „ 30th.	7		

100. ***Comparison with Usu-san eruption.*** (See fig. 24.) In the case of the Usu-sān eruption of 1910, the tremor-recorder observation made at Nishi-Monbets between July 31st and Aug. 6th, 1910, has given, for the decrease of the number of the volcanic outbursts, the following relation :*

$$\log y=0.8691-0.1152\ x, \dotfill (2)$$

in which y is the mean hourly frequency of the volcanic disturbances during the 24–hour time x, whose origin corresponds to the interval from noon, July 31st, to noon, Aug. 1st, or about 6 complete days after the commencement of the eruptions.

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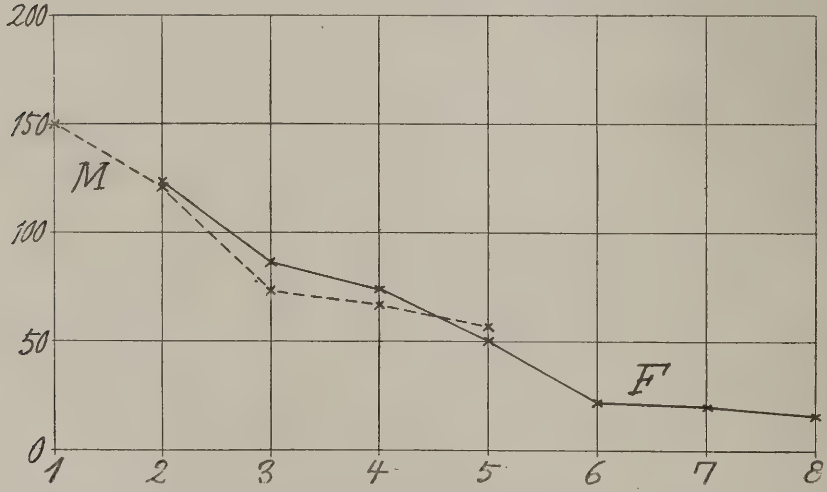
* The Bulletin, Vol. V., No. 1, p. 33, Equation (3), for which y is the mean hourly (not the 24-hourly, as by misprint has been put there) frequency of the eruptions during the 24 hours denoted by x.

On Aug. 3rd, the observation is wanting for the 6 hours between 2 and 8 A.M., the daily frequency of 73, enclosed in brackets, being $\frac{4}{3}$ of the number of the disturbances recorded during the remaining hours of the day, namely, 55.

The actual and calculated values of the frequency y are as follows :—

Date (Aug. 1910).	x	$24 \times y$ actual.	$24 \times y$ calculated (Eq. 2).
1st	0.5	151	155.5
2nd	1.5	121	119.2
3rd	2.5	55 (73)	91.5
4th	3.5	67	70.2
5th	4.5	57	53.8

Fig 24. Comparison of the Daily Eruption Frequency at Frusato with that at Nishi-Monbets.



F....Sakura-jima After-eruptions (1914) observed at Frusato.
M....Usu-san (Hokkaido) Outbursts in 1910, observed at Nishi-Monbets.

The successive 24-hourly values of the eruption frequency .... 121 ; 73 ; 67 ; and 57 for $x=1.5$; 2.5 ; 3.5 ; 4.5 ;.... for Nishi-Monbets, are nearly equal to those of the daily frequency for $x=0$, 1, 2.... for the Sakura-jima, namely, 124 ; 87 ; 74 ; 50 ; .. ; the coefficient of the x in Equation (2) for the former place, being about 0.12, which is not much different from that for the latter.

101. "*Small*"* *after-eruptions.* (See Table XXV and figs. 25 and 26.) Up to the 15th of February the small disturbances occurred so close to each other that it was impossible to count their number. For the next 6 weeks or so the individual disturbances could be distinguished more or less definitely; these being, however, very often confused by the volcanic micro-tremors (or oscillations) of fairly good size, which existed continuously. In this way the numbers of the small eruptions between Feb. 16th and the end of March (1914) given in Table XXV are to be regarded as giving only the roughly approximate values of the frequency of the comparatively well-defined small eruptions. Subsequently the motion of the ground was much reduced so that even very small disturbances could be counted with a tolerable degree of accuracy. This accounts partly for a marked frequency increase at the commencement of April.

According to Table XXV, the maximum daily number of the small disturbances was about 670, which corresponds to an average rate of one eruption in every 2 minutes. It was only after April 27th, that the daily frequency was reduced to about, or below, 100. From the graphical representation in fig. 25 it can be seen that the first maximum daily frequency (=486) took place on March 13th, the second (absolute) maximum (=672) on April 12th, and the third maximum (=204) on May 12th. It is interesting that these three days corresponded to a high-tide epoch in the Kagoshima bay, the moon having been full on the respective preceding days, namely, March 12th, April 11th, and May 10th. The final steady decrease of the eruptive activity seems to have began from April 12th, or three months after the first eruption on Jan. 12th.

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* See the Bulletin, Vol. VIII, No. 1, p. 26.

Fig. 25. Daily Frequency Variation of the Smaller Sakura-jima After-eruptions observed tromometrically at Frusato.

Feb. 16th—May 31st, 1914.

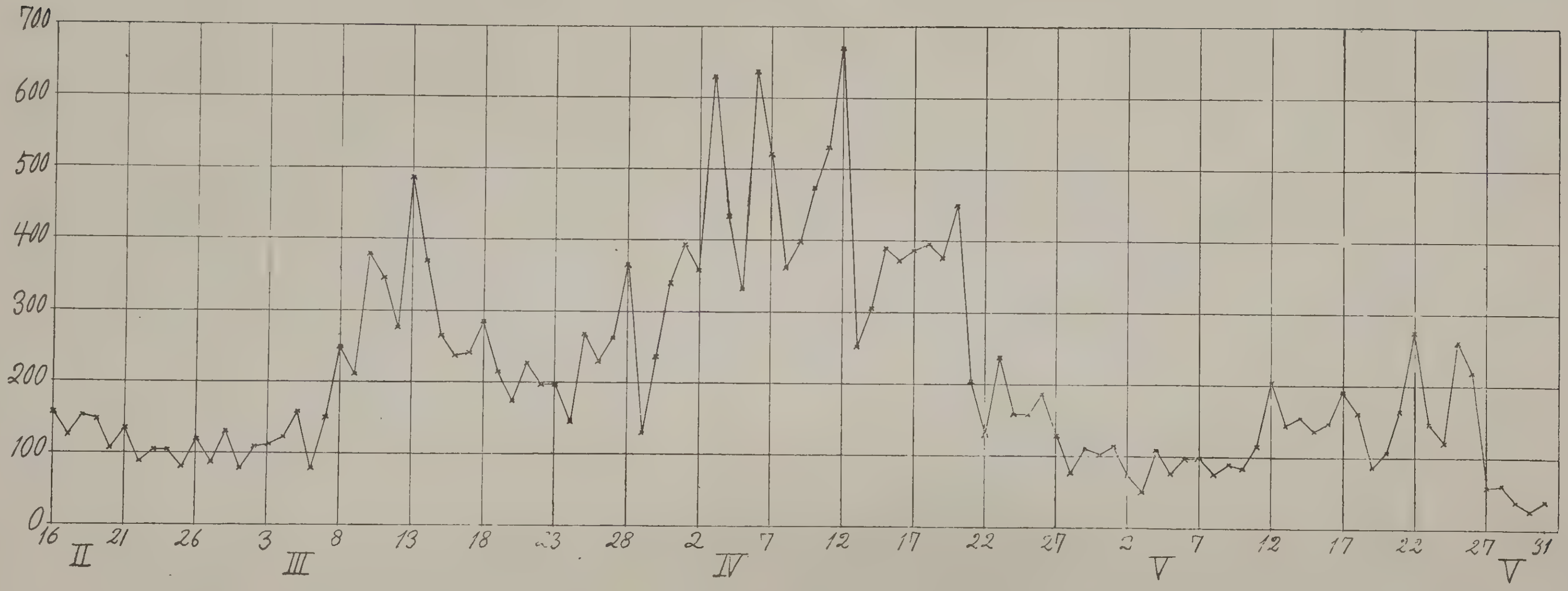


Fig. 26. Tromometer Observation at Frusato: Daily Frequency Variation of the Small Sakura-jima After-eruptions compared with that of the Loud Detonations.

A ...Loud Detonations. **B** Small After-eruptions.

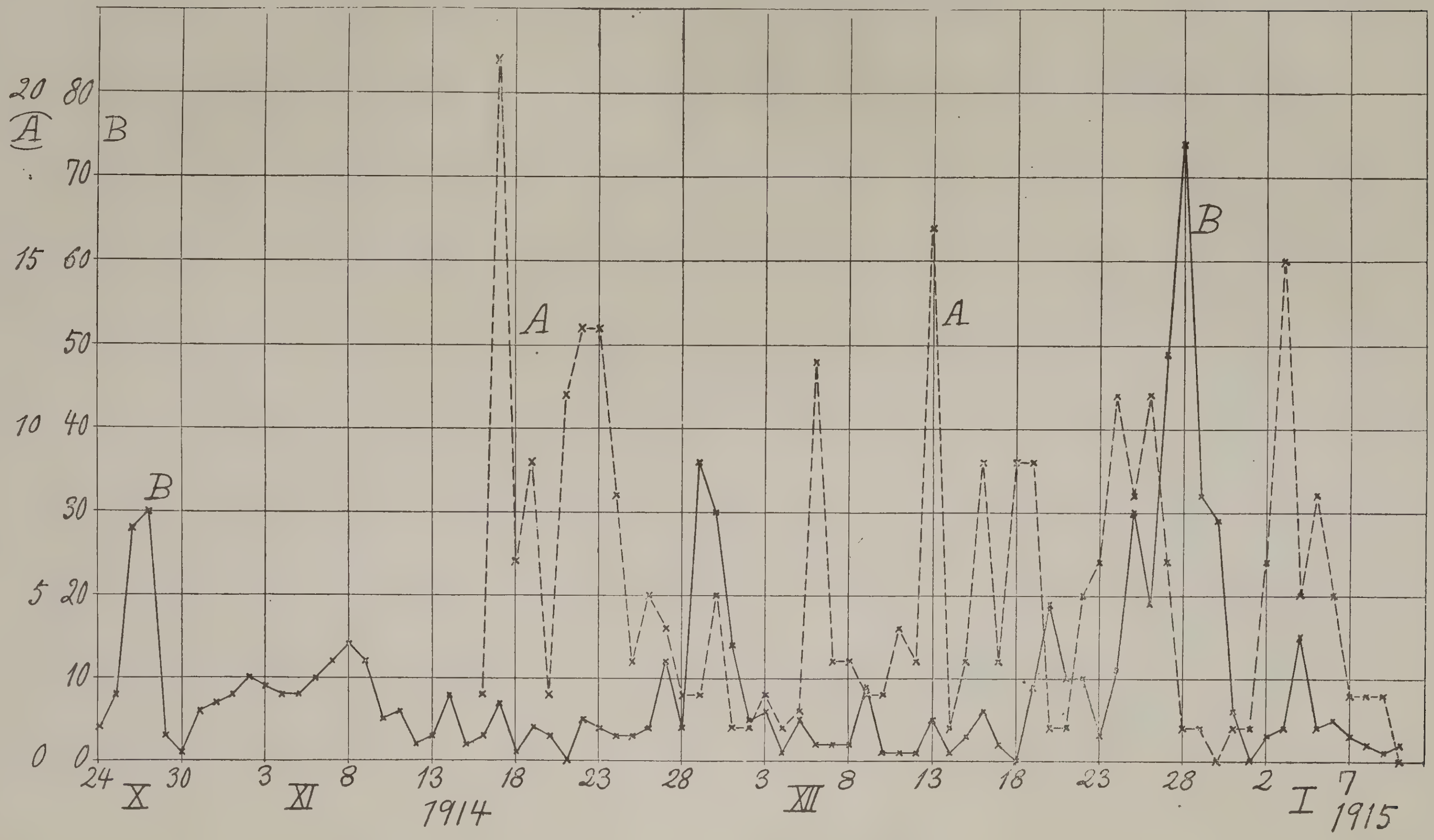


TABLE XXIII. 3-DAILY FREQUENCY VARIATION OF THE SAKURA-JIMA AFTER-ERUPTIONS TROMOMETRICALLY REGISTERED AT FRUSATO. FEB.–MAY, 1914.

3-day Interval.		Number of Eruptions.		3-day Interval.		Number of Eruptions.	
Month,	Days	Larger.	Smaller.	Month,	Days	Larger.	Smaller.
II,	16–18	443	32	IV,	11–13	1456	2
	19–21	384	25		14–16	1068	5
	22–24	296	17		17–19	1161	3
	25–27	286	18		20–22	783	3
	28–2	317	6		23–25	551	2
III,	3–5	392	2		26–28	390	2
	6–8	478	14		29–1	327	2
	9–11	938	8	V,	2–4	230	2
	12–14	1133	2		5–7	272	3
	15–17	743	0		8–10	246	2
	18–20	672	1		11–13	462	2
	21–23	621	5		14–16	435	6
	24–26	642	9		17–19	438	1
	27–29	760	8		20–22	544	5
	30–1	972	1		23–25	528	9
IV,	2–4	1423	0		26–28	339	3
	5–7	1492	4		29–31	103	6
	8–10	1237	5				

102. ***Comparison with "larger" after-eruptions.*** The 3-daily numbers of the large and small disturbances, between Feb. 16th and May 31st, are indicated in Table XXIII, the graphical illustration being given in fig. 27. From the latter, it will be observed that the two categories of the eruptions have a tendency of occurring in a symmetrical opposition. In Table XXIV, the 10-daily frequency variation of the larger after-eruptions is compared to that of the smaller. (See fig. 28.)

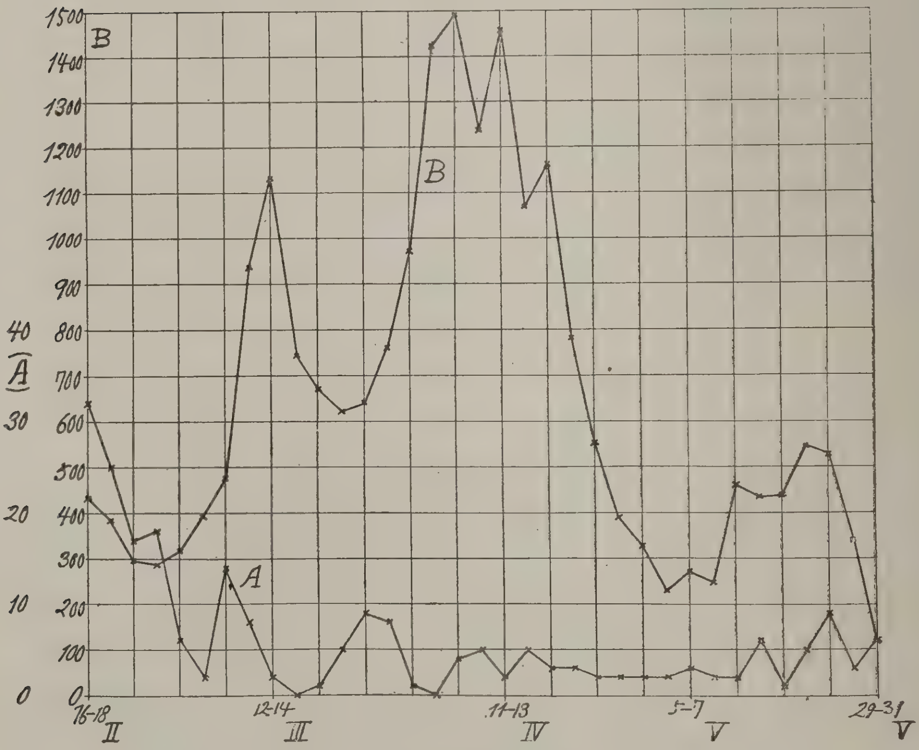
TABLE XXIV. 10-DAILY FREQUENCY VARIATION OF THE SAKURA-JIMA AFTER-ERUPTIONS TROMOMETRICALLY REGISTERED AT FRUSATO. FEB. 10TH, 1914 TO JAN. 10TH, 1915.

10-day Interval.	Number of After-eruptions.	
	Larger.	Smaller.
Feb. 10 — Feb. 19, 1914	422	—
„ 20 — March 1, „	51	1027
March 2 — „ 11, „	26	1917
„ 12 — „ 21, „	6	2775
„ 22 — „ 31, „	20	2373
April 1 — April 10, „	9	4547
„ 11 — „ 20, „	12	4136
„ 21 — „ 30, „	7	1486
May 1 — May 10, „	7	862
„ 11 — „ 20, „	9	1441
„ 21 — „ 30, „	23	1368
Oct. 24 — Nov. 2, „	7	98
Nov. 3 — „ 12, „	3	81
„ 13 — „ 22, „	4	32
„ 23 — Dec. 2, „	8	107
Dec. 3 — „ 12, „	0	30
„ 13 — „ 22, „	1	64
„ 23 — Jan. 1, 1915	3	250
Jan. 2 — „ 10, „	6	33

103. *Earthquake frequency.* The non-eruptive volcanic earthquakes were extremely few, there being only 10 between Feb. 15th and March 29th; while there was none of these after the latter date. It seems that the *frequent* occurrence of the earthquakes practically ended on Feb. 15th.

Fig. 27. Comparison of the 3-daily Frequencies of the Larger and Smaller Sakura-jima After-eruptions observed at Frusato.

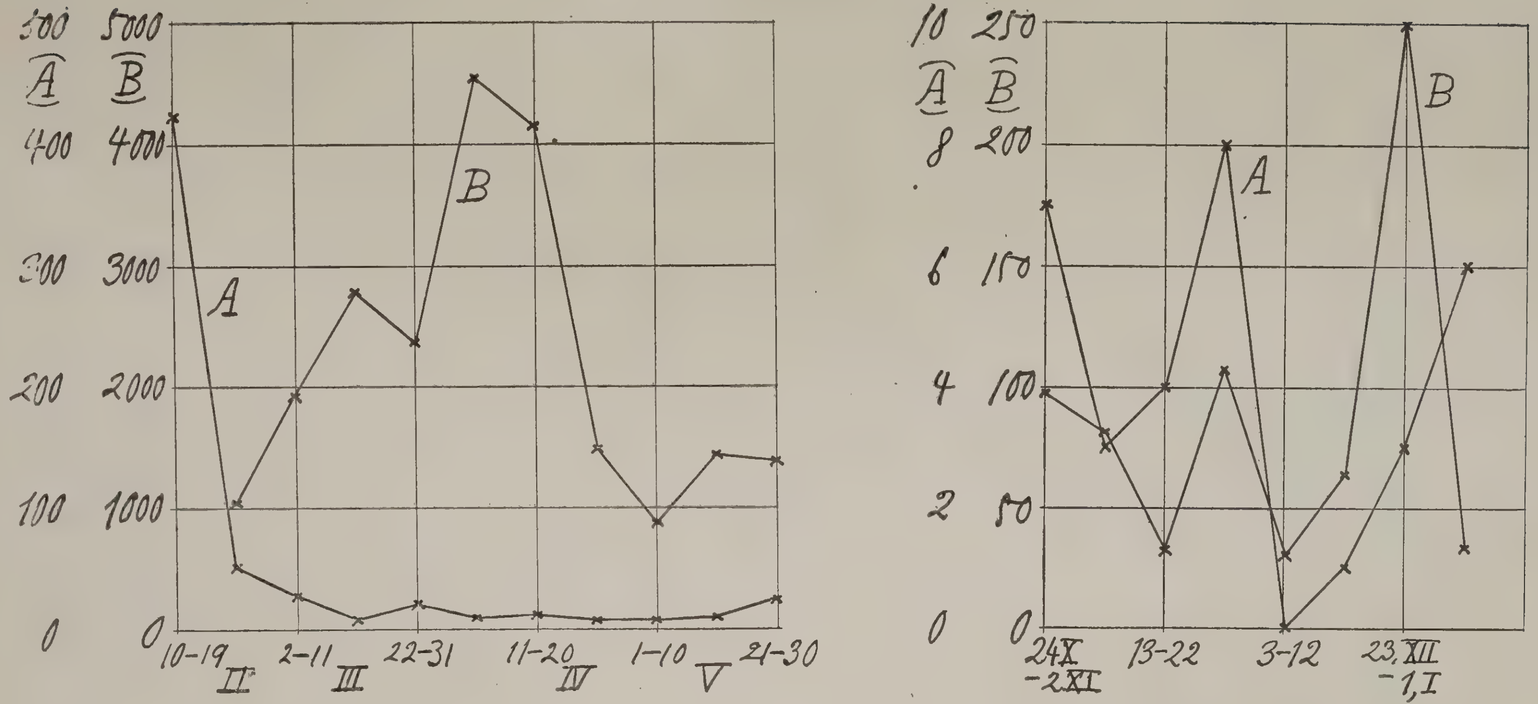
Feb. 16th—18th.... May, 29th—31st, 1914.



A........Larger After-eruptions.
B........Smaller ,,

Fig. 28. 10-daily Frequency Variation of the Larger and Smaller Sakura-jima After-eruptions observed at Frusato.

A.. .Larger After-eruptions. B ...Smaller After-eruptions.



Feb. to May, 1914.

Oct., 1914, to Dec., 1915.

TABLE XXV. DAILY NUMBERS OF THE SAKURA-JIMA AFTER-ERUPTIONS AND EARTHQUAKES TROMOMETRICALLY REGISTERED AT FRUSATO, FEB. 9TH—MAY 31ST, 1914.

Date. (1914.)	Daily Number of After-eruptions.		Volcanic Earthquakes not accompanied by outbursts.
	Larger.	Smaller.	
February, 9(1)	6	(Continuous.)	—
10	124	,,	1 (unfelt.)
11	87	,,	—
12	74	,,	—
13	50	,,	1(2)
14	22	,,	8(3)
15	20	,,	—
16	16	156	—
17	6	125	1
18	10	152	—
19	13	117	—
20	5	104	—
21	7	133	—
22	6	88	—
23	5	104	—
24	6	101	—
25	7	81	—
26	8	119	—
27	3	86	—
28	2	130	—
March, 1	2	78	—
2	2	109	1
3	1	112	—
4	—	122	—

(1) Registration commenced from $11^h\,13^m$ P.M.

(2) Earthquake of Iwō-jima.

(3) Of these 8, three were of *moderate* intensity, three were *slight*, one was unfelt, and the remaining one was of the Iwō-jima origin.

Date. (1914.)		Daily Number of After-eruptions.		Volcanic Earthquakes not accompanied by outbursts.
		Larger.	Smaller.	
March,	5	1	158	2
	6	1	78	—
	7	4	151	—
	8	9	249	—
	9	4	211	2
	10	3	381	—
	11	1	346	—
	12	1	277	—
	13	1	486	1
	14	—	370	—
	15	—	265	—
	16	—	236	1
	17	—	242	—
	18	1	285	—
	19	—	214	—
	20	—	173	—
	21	3	227	—
	22	1	197	—
	23	1	197	—
	24	4	144	—
	25	4	268	—
	26	1	230	—
	27	3	263	—
	28	—	367	—
	29	5	130	2
	30	1	237	—
	31	—	340	—
April,	1	—	395	—
	2	—	358*	—

* Almost continuous.

Date. (1914.)		Daily Number of After-eruptions.		Volcanic Earthquakes not accompanied by outbursts.
		Larger.	Smaller.	
April,	3	—	631*	—
	4	—	434*	—
	5†	1	304 (332)*	—
	6†	1	425 (638)*	—
	7	2	522*	—
	8	2	362*	—
	9	2	400*	—
	10	1	475*	—
	11	1	532*	—
	12†	1	636 (672)*	—
	13†	0	176 (252)*	—
	14	2	305*	—
	15	2	390*	—
	16	1	373*	—
	17	0	387*	—
	18	2	397	—
	19	1	377	—
	20†	2	428 (451)*	—
	21†	1	189 (203)*	—
	22	0	129	—
	23	1	237	—
	24	1	157	—
	25	0	157	—
	26	1	187	—
	27	0	128	—
	28	1	75	—
	29	2	110	—
	30	0	103	—
May,	1†	0	110 (114)	—

† See foot-note on next page.

Date. (1914.)		Daily Number of After-eruptions.		Volcanic Earthquakes not accompanied by outbursts
		Larger.	Smaller.	
May,	2	0	73	—
	3†	1	45 (49)†	—
	4	1	108	—
	5	0	77	—
	6	1	97	—
	7	2	98	—
	8	0	74	—
	9	2	89	—
	10	0	83	—
	11	—	115	—
	12	1	204	—
	13†	1	135 (143)	—
	14†	3	123 (153)	—
	15	3	136	—
	16	—	146	—
	17	1	192	—
	18	—	160	—
	19	—	86	—
	20	—	106	—
	21	2	164	—
	22	3	274	—
	23	2	147	—
	24	1	120	—
	25	6	261	—
	26	1	219	—
	27	—	58	—
	28	2	62	—
	29	3	38	—
	30	3	25	—
	31	—	40	—

† Observation wanting for some time interval. The approximate daily frequency (enclosed in brackets) have been deduced by proportion from the actual observed value.

TABLE XXVI. DAILY NUMBER OF THE SAKURA-JIMA DETONATIONS AND AFTER-ERUPTIONS TROMOMETRICALLY REGISTERED AT FRUSATO. OCT. 24TH, 1914 TO JAN. 10TH, 1915.

Date.	Daily Number of Detonations.		Daily Number of After-eruptions.		Volcanic Earthquakes not accompanied by outbursts.
	Strong.	Feeble.	Larger.	Smaller.	
1914					
October 24	1		0	4	
25	9		0	8	2
26	3		1	27	3
27	3		0	30	2
28	0		1	2	
29	0		0	1	1 (sensible)
30	1		2	4	
31	1		1	6	
November 1	2		0	8	
2	2		2	8	
3	5		1	8	
4	2		1	7	1
5	4		0	8	
6	3		0	10	
7	5		1	11	
8	2		—	14	
9	0		—	12	
10	2		1	4	
11	5		1	5	
12	0		—	2	
13	1		—	3	
14	1		1	7	
15	0		—	2	
16	1	1	—	3	
17	10	11	1	6	
18	2	4	1	—	

Date.	Daily Number of Detonations.		Daily Number of After-eruptions.		Volcanic Earthquakes not accompanied by outbursts.
	Strong.	Feeble.	Larger.	Smaller.	
1914					
November 19	2	7	—	4	
20	0	2	—	3	
21	6	5	—	—	
22	10	3	1	4	
23	10	3	2	2	
24	6	2	1	2	
25	0	3	1	2	
26	2	3	1	3	
27	1	3	1	11	
28	1	1	—	4	
29	1	1	—	36	
30	0	5	1	29	
December 1	0	1	—	14	
2	0	1	1	4	
3	0	2	—	6	
4	0	1	—	1	
5	3	3	—	5	
6	2	10	—	2	
7	0	3	—	2	
8	0	3	—	2	
9	0	2	—	9	
10	0	2	—	1	
11	2	2	—	1	
12	0	3	—	1	
13	2	14	—	5	
14	0	1	—	1	
15	0	3	—	3	
16	1	8	—	6	

Date.	Daily Number of Detonations.		Daily Number of After-eruptions.		Volcanic Earthquakes not accompanied by outbursts.
	Strong.	Feeble.	Larger.	Smaller.	
1914					
December 17	0	3	1	1	
18	1	8	—	—	
19	0	9	—	9	
20	0	1	—	19	
21	0	1	—	10	
22	1	4	—	10	
23	1	5	—	3	
24	3	8	—	11	
25	2	6	—	30	
26	5	6	—	19	
27	3	3	—	49	
28	0	1	1	73	
29	0	1	—	32	
30	0	0	—	29	
31	1	0	2	4	
1915					
January 1	0	1	—	—	
2	0	6	2	1	
3	11	4	1	3	
4	0	5	—	15	
5	6	2	1	3	
6	3	2	—	5	
7	1	1	—	3	
8	1	1	—	2	
9	1	1	—	1	
10			2	—	

TABLE XXVII. MEAN DAILY BAROMETRIC PRESSURE IN KAGOSHIMA, FEB. TO MAY, 1914. 700 mm.+

(Reduced to See-level and Standard Gravity)

Month, Year. / Day.	II, 1914.	III, 1914.	IV, 1914.	V, 1914.	X, 1914.	XI, 1914.	XII, 1914.	I, 1915.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
1	65.25	65.72	61.08	62.32	58.78	70.01	65.34	66.99
2	64.75	57.47	56.05	61.13	64.52	70.37	63.67	66.24
3	67.42	62.11	61.19	64.35	66.19	67.32	65.11	66.77
4	68.43	63.70	61.77	65.88	65.30	62.76	63.67	69.41
5	64.70	63.35	62.81	63.02	64.06	61.71	62.64	69.34
6	62.33	56.71	63.12	61.62	63.69	63.92	62.80	67.82
7	65.00	58.51	60.03	59.81	60.90	66.73	66.04	57.97
8	59.10	60.65	61.20	60.40	60.69	67.29	68.59	60.02
9	63.37	59.51	65.52	59.50	62.58	63.53	69.45	67.16
10	66.08	61.96	65.22	58.17	62.66	65.42	68.20	65.39
11	64.90	59.94	63.01	63.67	60.99	68.75	65.60	60.00
12	66.98	59.67	62.05	58.43	62.55	66.38	62.91	64.00
13	68.62	58.17	56.63	59.67	64.70	64.89	65.60	68.39
14	69.95	60.73	56.88	57.40	65.64	61.48	64.60	71.01
15	66.55	67.60	60.62	56.33	66.05	63.11	63.21	72.26
16	64.96	69.25	58.91	57.04	67.04	65.87	65.83	69.36
17	66.66	66.96	62.90	60.35	67.12	64.49	66.14	70.46
18	60.88	65.78	67.03	62.52	64.59	61.25	66.06	70.98
19	60.83	69.58	66.28	60.09	62.59	62.31	67.06	64.14
20	62.27	66.35	61.10	55.11	61.96	59.34	66.49	64.75
21	62.57	61.97	62.41	56.60	66.63	61.16	64.61	67.46
22	61.62	61.75	61.70	63.90	67.50	65.08	56.49	66.54
23	61.58	58.60	58.15	61.61	68.42	66.55	60.52	67.04
24	65.85	57.67	56.21	58.14	67.67	62.34	68.11	69.87
25	62.22	62.32	57.37	63.39	64.57	65.09	67.07	71.51
26	63.80	66.22	60.38	65.36	64.67	66.34	65.20	71.12
27	69.10	70.54	56.21	62.41	64.43	67.35	71.01	66.42
28	70.22	70.93	56.90	58.40	63.27	70.30	71.70	60.75
29		67.59	62.37	54.86	61.68	69.24	70.06	68.60
30		58.61	64.39	57.95	61.99	67.59	69.15	70.52
31		60.67		60.44	67.10		67.59	65.20
Mean.	64.85	62.92	60.98	60.00	64.21	65.27	65.82	67.02

CHAPTER VII. BAROGRAPH OBSERVATION AT FRUSATO OF THE SAKURA-JIMA AFTER-EXPLOSIONS.

104. ***Open barograph record of Sakura-jima explosions.*** The observation of the air disturbances caused by the Sakura-jima after-explosions was carried on at Frusato on the 12th to 15th, Feb., 1914, by means of a Richard's barograph adapted to the smoked paper registration in the same way as had been tried in 1913 at the Yuno-taira seismological station on the Asama-yama*. In this way, well defined open time-scale barograms were obtained on Feb. 14th and 15th as follows:

(i)	Feb.	14th,	1914, at	11. 58. 45	A.M.
(ii)	„	„	„ ,	1. 30. 53	P.M.
(iii)	„	„	„ ,	10. 40. 53	P.M.
(iv)	„	15th,	„ ,	0. 41. 34	A.M.

The explosions on these occasions proceeded from the craterlet No. 2 on the eastern, or Nabe-yama, side of the Sakura-jima, which was then in full activity. The source of disturbance was situated 3500 metres to the N. 35° E. of the observing place at Frusato. The magnified diagrams are reproduced in figs. 30,31 and 31.

105. ***After-eruption of Feb. 14th, 1914, at 11.58.45*** A.M. The barometric disturbance was small and composed of an increase of 0.87 mm. (duration=about 0.44 sec.) and the counter change of 1.06 mm. (duration=about 1.1 sec.); the pressure being gradually brought back to the original height in the course of the next 3.6 sec. Total duration=15 sec.

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* See the Bulletin, Vol. VII, No. I.

106. ***After-eruption of Feb. 14th, 1914, at*** **1.30.53 P.M.** The principal oscillation of the barometric disturbance was 2.1 sec. in period and consisted of a sudden pressure increase of 2.6 mm., followed by the counter change of 3.5 mm.; resulting in the reduction of the pressure by the amount of 0.8 mm. below the equilibrium condition. The next displacement of 0.85 mm. practically brought the disturbance to end, the three first movements together lasting 3.1 sec. For the subsequent 17 sec., there were very small traces of air vibrations of $T=3.5$ sec., mixed with those of about half period. Total duration$=$20 sec.

This barometric disturbance was produced by an outburst from the Nabe-yama craterlet, whose earthquake motion was tromometrically observed at Frusato, as described next.

Tromometer diagram. The earthquake motion, whose preliminary portion was confused by micro-tremors, began at 1.30.44 P.M. or 9 sec. before the arrival of the barometric disturbance. The 1st displacement was 0.038 mm. (duration$=$1.34 sec.) directed toward the crater. The co-existing transverse motion of 0.016 mm. is to be regarded as belonging to the micro-tremors. The counter, or outward, longitudinal motion of 0.085 mm. (duration$=$1.9 sec.) corresponded approximately to the two transverse displacements of 0.050 and 0.112 mm. which together formed a vibration of $T=2.45$ sec. The next vibration, of $T=2.67$ sec., was composed of the following two displacements. (1), 0.138 mm. toward the crater, 0.144 mm. toward the S.E. (absolute maximum in the transverse component); resultant $2a=0.20$ mm. toward the E. (2), 0.066 mm. away from the crater, 0.091 mm. toward the N.W.; resultant $2a=0.113$ mm. toward W.9°N. The motion continued large further for 7.9 sec. in the longitudinal and for 4.0 sec. in the transverse component; the absolute maximum vibration in the former direction being $2a$=about 0.204 mm., T=2.64 sec., which occurred 7.3 sec. after the commencement. From about 10.1 sec. after the same time moment there appeared, both in the longitudinal and the transverse components, quick vibrations of T=about 0.7 sec., max. $2a$= 0.047 mm. in each direction. Total duration=60 sec. approx.

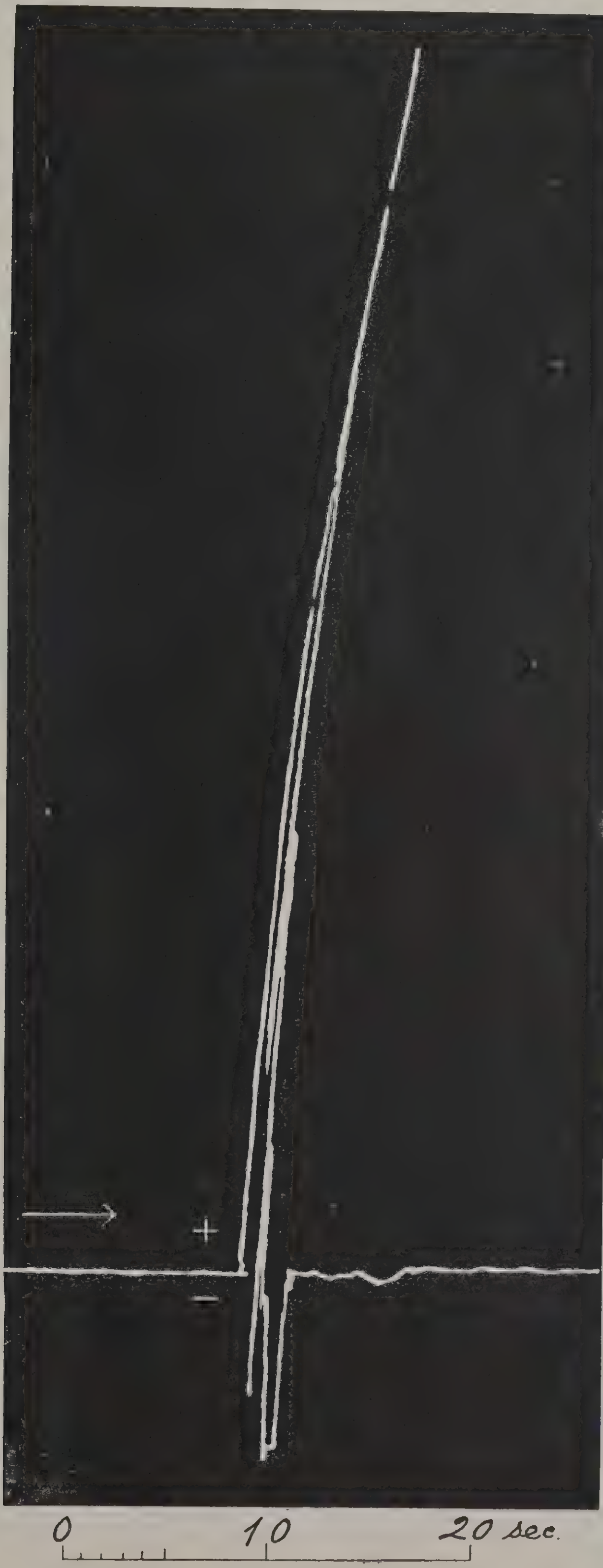
The *micro-pulsatory vibrations or micro-tremors*, which existed about the time of the after-eruption in question, were as follows:—

Longitudinal Component. sec.	Transverse Component.
0.85 (2a=0.02 mm.)	0.89 (max. 2a=0.01 mm.)
0.93	0.96
1.28 (2a=0.016 mm.)	1.80 (max. 2a=0.021 mm.)
	1.90 („ =0.013 „)
2.50	1.15 („ =0.009 „)
2.30 (2a=0.036 mm.)	2.20 („ =0.022 „)
2.28	

107. ***After-eruption of Feb. 14th, 1914, at 10.40.53* P.M.** The initial and principal vibration of the barometric disturbance was made up of an increase of 2.2 mm. (duration=about 0.59 sec.), followed by the counter change of 2.9 mm. (duration = about 1.3 sec.). The pressure was gradually restored to the original condition in the course of the next 3.9 sec., very slight movements continuing for further 8 sec. Total duration=14 sec.

108. ***After-eruption of Feb. 15th, 1914, at 41.34* A.M.** The barometric disturbance was comparatively large and began with a sudden pressure increase of 5.95 mm., about 0.45 sec. in duration. The counter motion of 6.85 mm. about 1.6 sec. in duration, was mixed up with the smaller and quicker vibrations about 0.45 sec. in period. The 3rd displacement of 0.9 mm. brought back the barometric pressure to the level before the disturbance, which so far lasted 2.8 sec. During the next 20 sec., there were very slight

Fig. 29. Barograph Observation at Frusato of the Sakura-jima After-eruption on Feb. 15th, 1914, 0. 41. 34. A. M. Magnification = 28.



PL. LXXXVII.

Open Time-scale Barograph Observation at Frusato of the Sakura-jima After-eruptions.

Magnification = 18.

Fig. 30.
Feb. 14th, 1914;
1. 30. 53. P. M.

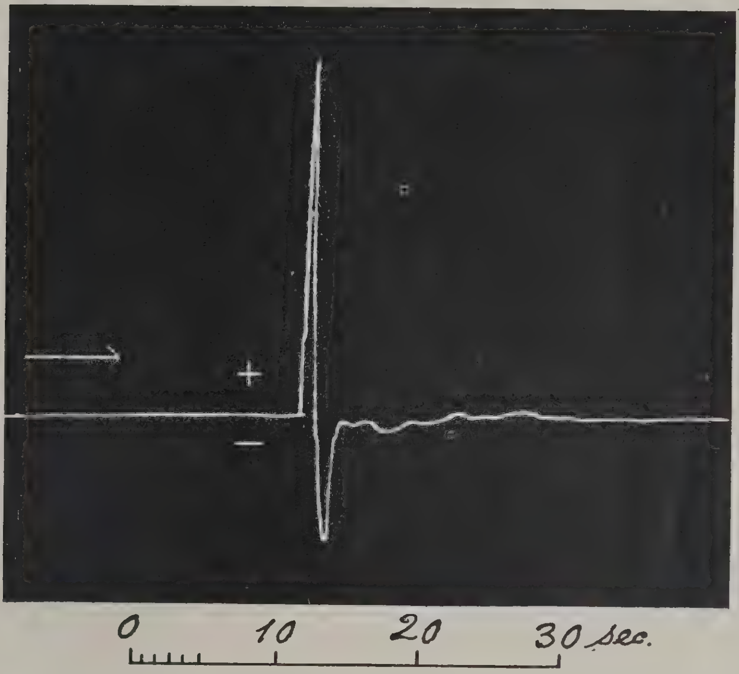
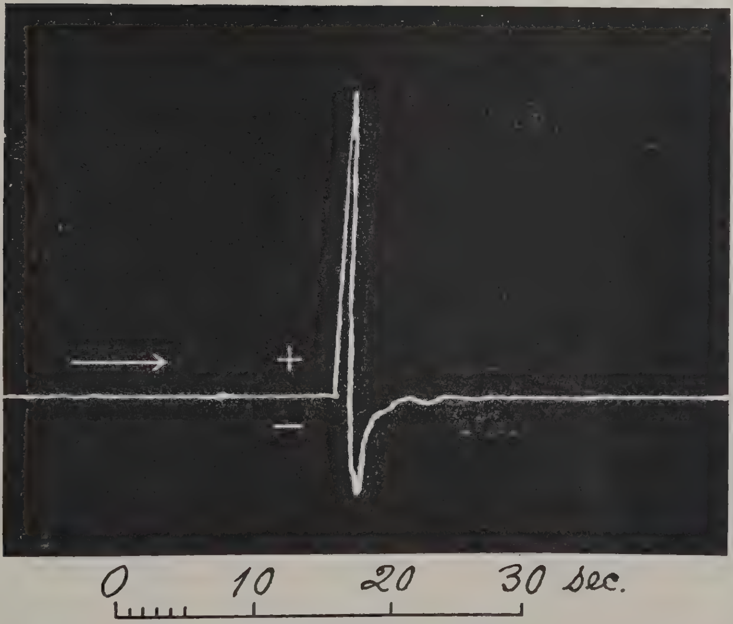


Fig. 31.
Feb. 14th, 1914;
10. 40. 53. P. M.



tracess of $T=2.1$ sec. (?) mixed with quicker ones. Total duration $=23$ sec.

TABLE XXVIII. BAROGRAPH OBSERVATION OF THE SAKURA-JIMA AFTER-ERUPTIONS AT FRUSATO, COMPARED TO THAT OF THE ASAMA-YAMA EXPLOSIONS OBSERVED AT YUNO-TAIRA.

Date.	Time of Occurrence.	Principal Barometric Oscillation.		Duration of			
		1st Displt.: Pressure Increase.	2nd Displt.: Pressure Decrease.	1st Displt.	2nd Displt.	Princ. Portion.	Total Disturbance.
	Sakura-jima.						
Feb. 14, 1914.	11.58.45 A.M.	0.87 mm.	1.06 mm.	0.44 sec.	1.10 sec.	3.6 sec.	15. sec.
,,	1.30.53 P.M.	2.6	3.5	(2.1 sec.)		3.1	20
,,	10.40.53 P.M.	2.2	2.9	0.59	1.3	3.9	14
Feb. 15, 1914.	0.41.34 A.M.	5.95	6.85	0.45	1.6	2.8	23
Mean				0.49 sec.	1.3 sec.	3.4 sec.	18 sec.
	Asama-yama.						
Aug. 12, 1913.	7. 45 P.M.	2.8 mm.	3.2 mm.	(2.7 sec.)			7.1 sec.
,,	10. 20 P.M.	>11 mm.	>13 mm.				
May 5, 1914.	0. 33 A.M.	6.4	7.0	(2.3 ,,)			12.3 ,,

109. ***Summary.*** The barometric effect of the explosion consisted in each case mainly in the production of a single compressional oscillation, whose average period was 1.9 sec., and which was composed of the 1st displacement, or the pressure increase, and the 2nd displacement, or the pressure decrease. The latter was greater than the former in the mean ratio of 1.3 to 1. (See Table XXVIII.) Further, the semi-periods or durations corresponding to the two displacements were unequal, the respective average values being 0.49 sec. and 1.3 sec. The duration of the 1st pressure increase may probably be taken as giving approximately the duration of the explosive action at the craterlet itself, the strong detonative outburst thus lasting about ½ sec. The duration of the 2nd displacement or pressure decrease, =1.3 sec., may be taken as indicating the time length of the continuance of the powerful inrush of the air which immediately set in after the termination of the eruption. The general nature of the barometric disturbance caused by the Sakura-jima outbursts was quite similar to that in the case of the Asama-yama explosions observed in 1913.

Tokyo. April, 1920.

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OF THE

IMPERIAL EARTHQUAKE INVESTIGATION COMMITTEE

Vol. VIII. No. 6.

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F. OMORI. The Sakura-jima Eruptions and Earthquakes. VI.

Tokyo, November, 1922.

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The Sakura-jima Eruptions and Earthquakes. VI.

[Notes on the Destructive Earthquake of Jan. 12, 1914, and Miscellaneous Remarks on the Eruptions of Sakura-jima.]

By **F. OMORI.**

(*With Plates* LXXXVIII–CVII.)

CHAPTER I. NOTES ON THE DESTRUCTIVE SAKURA-JIMA EARTHQUAKE OF JAN. 12, 1914.

1. Time of Occurrence. The destructive Sakura-jima earthquake on Jan. 12, 1914, was tromometrically observed at the Seismological Institute and the Osaka meteorological observatory at the radial distances of 958 and 560 km. respectively, as follows :—

	Time of Commencement.	Duration of the 1st prel. tremor.
Seismological Institute (Tokyo) ...	6^h 30^m 21^s P.M.	130.7 sec.
Osaka Met. Observatory.	6 29 28	70.9

The time of earthquake commencement at the origin itself estimated from the Tokyo and Osaka observations is found to be 6. 27. 57 P.M., or very nearly 6^h 28^m P.M.

The maximum frequency of the fore-shocks of different intensities taken together was attained between 8 P.M. on the 11th and 10 A.M. on the 12th, that is to say, during the 14 hours preceding the commencement of the actual eruption. If we confine our attention to the stronger of the fore-shocks, namely, those of moderate and strong intensities, the maximum frequency occurred between about 6 and 11 P.M. on the 11th. (See Table I.) It may be concluded that the premonitory earthquakes, which were the result of the underground volcanic tension trying to create the exits for the emission of the eruptive materials, had already reached the climax in frequency and intensity some dozen hours prior to the outburst. The violent and fairly extensive earthquake at 6. 28 P.M., on the 12th, took place, on the other hand, about 8½ hours after the commencement of the latter, and is to be considered, not as belonging to the group of the fore-shocks, but as a non-local tectonic disturbance induced by the volcanic eruption.

Table I. List of Moderate and Strong Earthquakes felt in Kagoshima in Jan. 1914.

Time of Occurrence.	Intensity.
Jan. 11, 1914.	
h m s	
4 01 40 A.M.	Moderate.
4 26 40	" Houses shaken.
5 58 00	" "
9 57 45	Strong. Clocks stopped.
11 46 54	Moderate. Houses shaken.
0 27 11 P.M.	" Strong vert. motion. Ground cracked.
0 43 00	Strong. Clocks stopped.
1 24 00	Moderate. Houses shaken.
2 54 50	" "
3 52 10	" "
4 12 10	" "
5 24 00	" "
6 47 00	" "
6 53 00	" "
7 01 00	" "
7 22 10	" "
7 30 20	" "
7 42 02	" "
7 51 00	" "
8 12 00	" "
8 23 00	" "
8 34 00	" "
Jan. 11, 1914.	
h m s	
9 00 00 P.M.	Moderate. Houses shaken.
9 08 00	" "
9 52 00	" "
9 59 00	" "
10 00 00	" "
10 24 00	" "
10 58 00	Strong. "
Jan. 12, 1914.	
0 40 00 A.M.	Strong. Houses shaken.
3 35 00	Moderate. "
4 08 00	" "
4 43 00	" "
5 49 00	Strong. "
6 03 00	Moderate. "
6 15 30	" "
6 32 00	" "
7 46 00	" "
8 27 00	Strong. "
6 28 00 P.M.	**Destructive.**
Jan. 13, 1914.	
4 09 00 P.M.	Strong. Houses shaken.

2. **Tokyo Registers.*** The different tromometers in the Seismological Institute (Hongo, Tokyo) have given well defined registers of the destruc-

---

* Record at the Kagoshima Meteorological Observatory of the commencement of the destructive earthquake motion has been reproduced in No. 5 of this Volume.

tive Sakura-jima earthquake on Jan. 12, 1914. Figs. 2, A and 2, B (Pls. LXXXIX., A and B) is a slightly enlarged reproduction (magnification = 26) of the earlier and the main portions of the diagram furnished by the duplex pendulum tromometer, composed of the upper, or ordinary, pendulum of height = 4.0 m. and of weight = 150 kg., and of the lower, or inverted pendulum of height = 0.58 m. and of weight = 32 kg., with the resultant oscillation period of 19 sec. From the diagram it will be seen that the movements in the preliminary tremor, 2 m. 9.3 sec. in duration, were executed in the S. W.–N. E. directions ; the very first displacement being, according to the high magnification instrument registers, in the direction of N. 64° E., accompanied by an upward movement. The seismic origin was, therefore, at the approximate distance of 960 km. to the S. 64° W. of Tokyo, a position quite close to Sakura-jima. In the principal portion, the motion was composed at first of the transverse vibration, but subsequently again of the large longitudinal vibration, followed by alternations of the two sets of waves of gradually decreasing amplitude.

The maximum movements (= 2a) recorded by the different instruments at the Seismological Institute was as follows :—

	Magnification.	Actual 2a.
E. W. Compt. Horizontal Pendulum	(= 10), ...	...2.95 mm.
,, ,, ,,	(= 15), ...	...2.90 ,,
,, ,, ,,	(= 30), ...	...2.83 ,,
		Mean...**2.9** ,,
N. S. ,, ,, ,,	(= 10), ...	...1.65 mm.
,, ,, ,, ,,	(= 20), ...	...1.40 ,,
		Mean...**1.6** ,,
Vertical Component Tromometer	(= 10), ...	...0.7 mm.

To give a comparison, the maximum motion (= 2a) of the local semi-destructive Asama-yama earthquake of July 16, 1912, registered in Tokyo at the radial distance of 135 km. was as follows :—

	Magnification.	Actual 2a.
E. W. Compt. Horizontal Pendulum,	(= 10) ...	...1.65 mm.
,, ,, ,,	(= 15) ...	...1.53 ,,
,, ,, ,,	(= 30) ...	...1.95 ,,
		Mean...**1.71** ,,
N. S. ,, ,, ,,	(= 10) ...	...2.45 mm.
Vertical Compt. Tromometer	(= 10) ...	...0.70 ,,

Taking the distance difference into consideration, the Sakura-jima earthquake on Jan. 12, 1914, seems to have been some 10 times larger than this strong volcanic Asama earthquake.

Figs. 3, 4, and 5 (Pl. XC.) give the E. W., the N. S., and the vertical component registers at Hongo of the Sakura-jima earthquake.

3. **Area of Earthquake Motion.** The Sakura-jima earthquake was fairly great, and the area of sensible motion included the whole of Kyushu (except the province of Chikzen at the north), the S.W. extremity of Chugoku, and the N.W. portion of Shikoku, extending to the maximum distance of 360 km. in the N.E. direction to the vicinity of Hiroshima (province of Aki) and Imahal (province of Iyo, Shikoku). Toward the S.S.W. the shock was felt at the islands of Akseki-jima (惡石嶋) and Takara-jima (寳嶋) at the radial distance of about 350 km., but was unfelt at Nase (O-shima, Lyukyu) a little futher on. Toward the N.W. the radial distance of the sensible motion area was limited to 210 km., the shock having been felt at the S.W. part of the Goto islands group, but not felt at the islands of Iki and Tsushima. It is likely that the sensible motion was propagated also to a comparatively short distance toward the S.E.

The area of moderate intensity motion which included the whole central and southern parts of Kyushu and some of the Satsuma islands, had the maximum radial distance of about 185 km., to Nagasaki and the vicinity toward the N.N.W., and the Yaku-shima (屋久嶋) and Nakano-shima (中之嶋) toward the S.S.W.

The area in which the earthquake was felt strongly without causing damage extended over Satsuma, Osumi (except its eastern portion), and the Koshiki-jima islands (上下甑嶋), the maximum radial distance being 70; 90; and 80 km. toward the N.; the W.; and the S.S.W. respectively.

The area of strong motion, in which slight damage was caused, was an ellipse including the region bordering on the Inner Kagoshima Bay, of the major and minor diameters of 60 and 45 km. respectively.

Finally, the violent motion area, in which serious damage was caused to the buildings, was a small ellipse including the island of Sakura-jima and the city of Kagoshima and the vicinity, with the major and minor diameters of 30 and 25 km. respectively. At the Moe-jima, off the N.E. coast of Sakura-jima, the earthquake was not very severe, none of the tomb-stones having been overturned.

From the map (fig. 1) it will be observed that the sensible earthquake motion was mainly propagated toward the N.E. and toward the S.S.W., namely, along the extension of the Japan islands arc. Such was also the case with the

Pl. LXXXVIII.

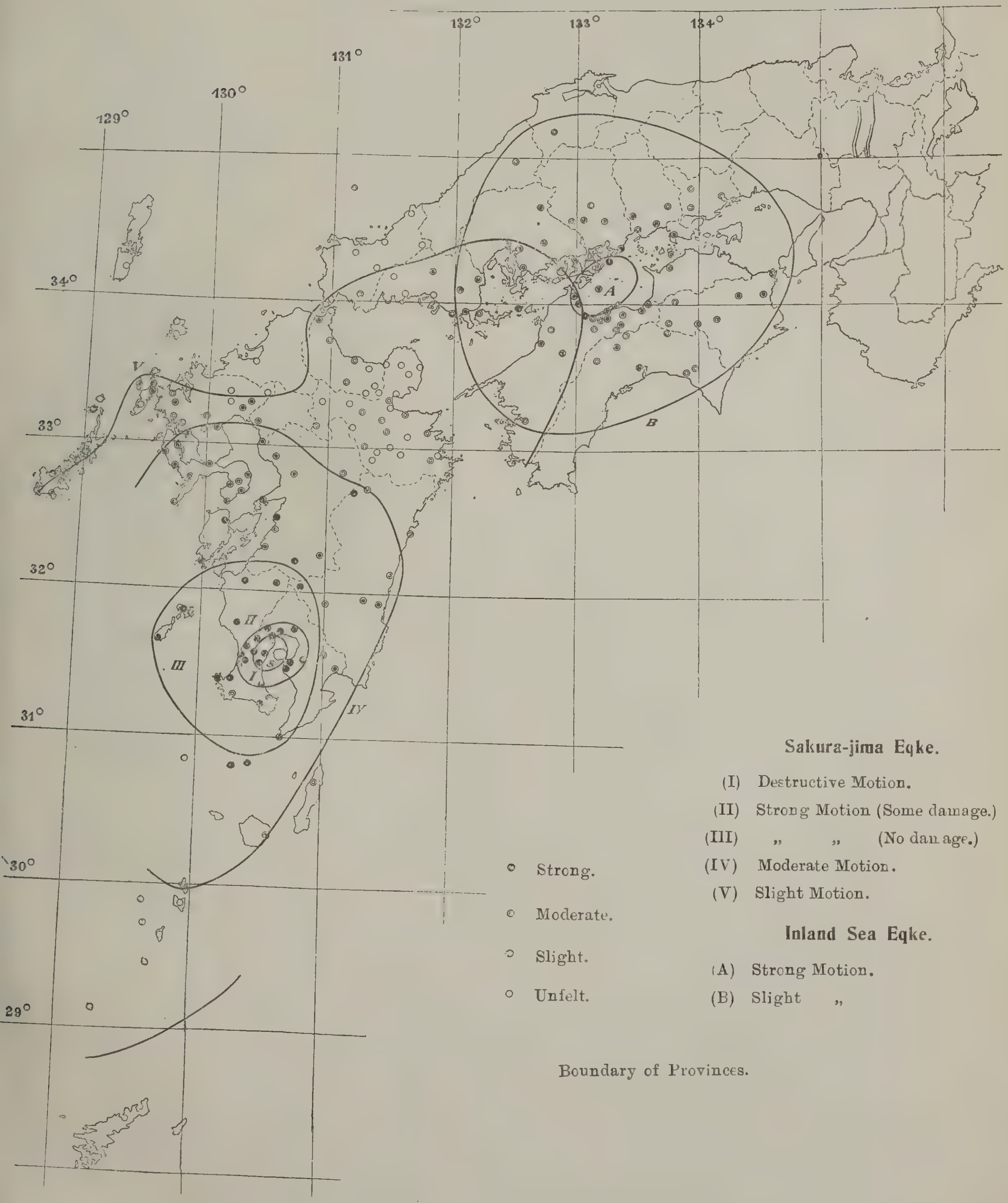
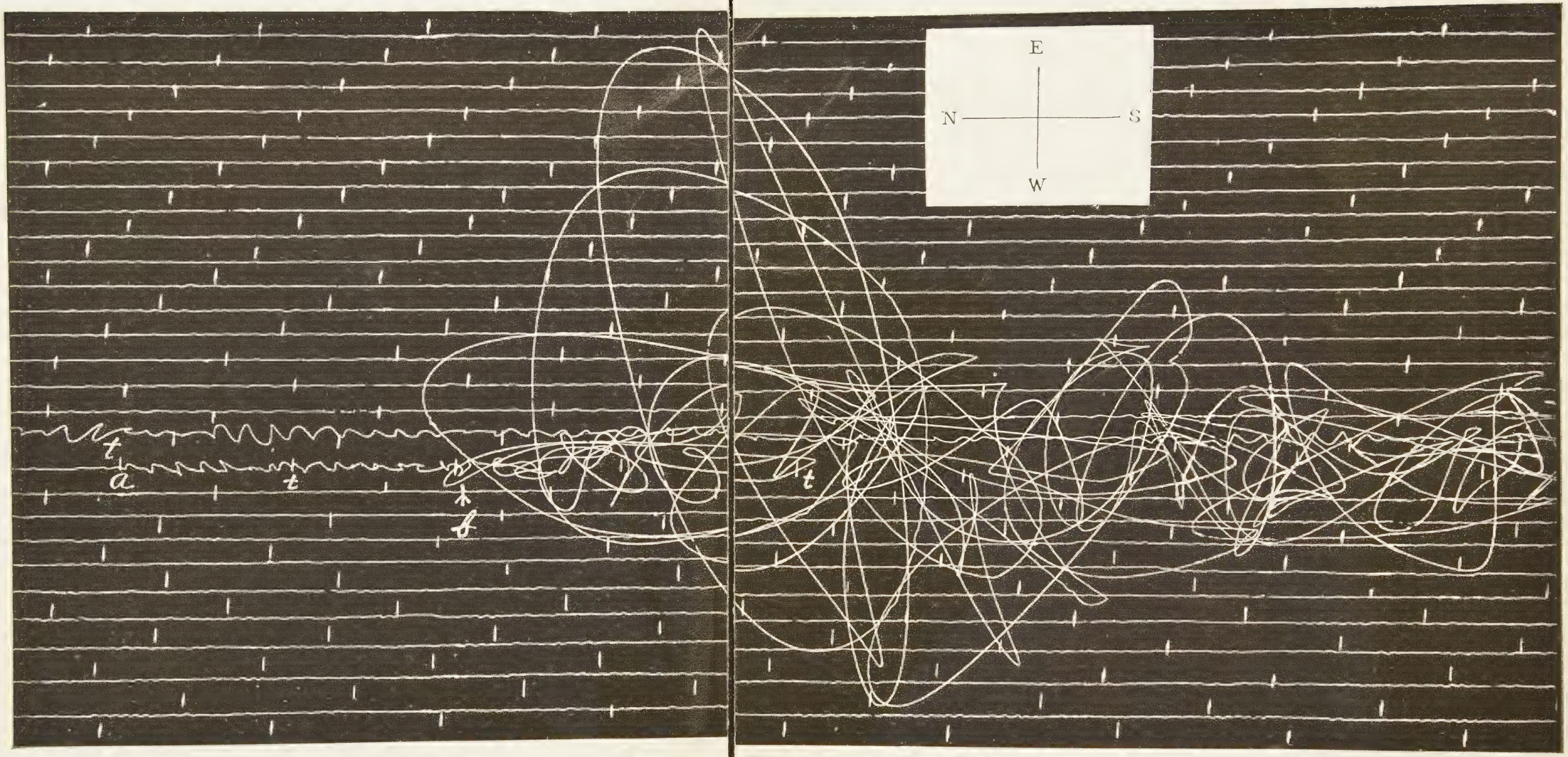


Fig. 1. Map showing the Area of Disturbance of the Sakura-jima and the Inland Sea Earthquakes on Jan. 12, 1914.

Pl. LXXXIX. A.

Figs. 2, A and B. Duplex Pendulum Observation in Tokyo, of the Sakura-jima Earthquake on Jan. 12, 1914. Magnification=26.

Fig. 2, A.



a .....Commen ement of the Earthquake.

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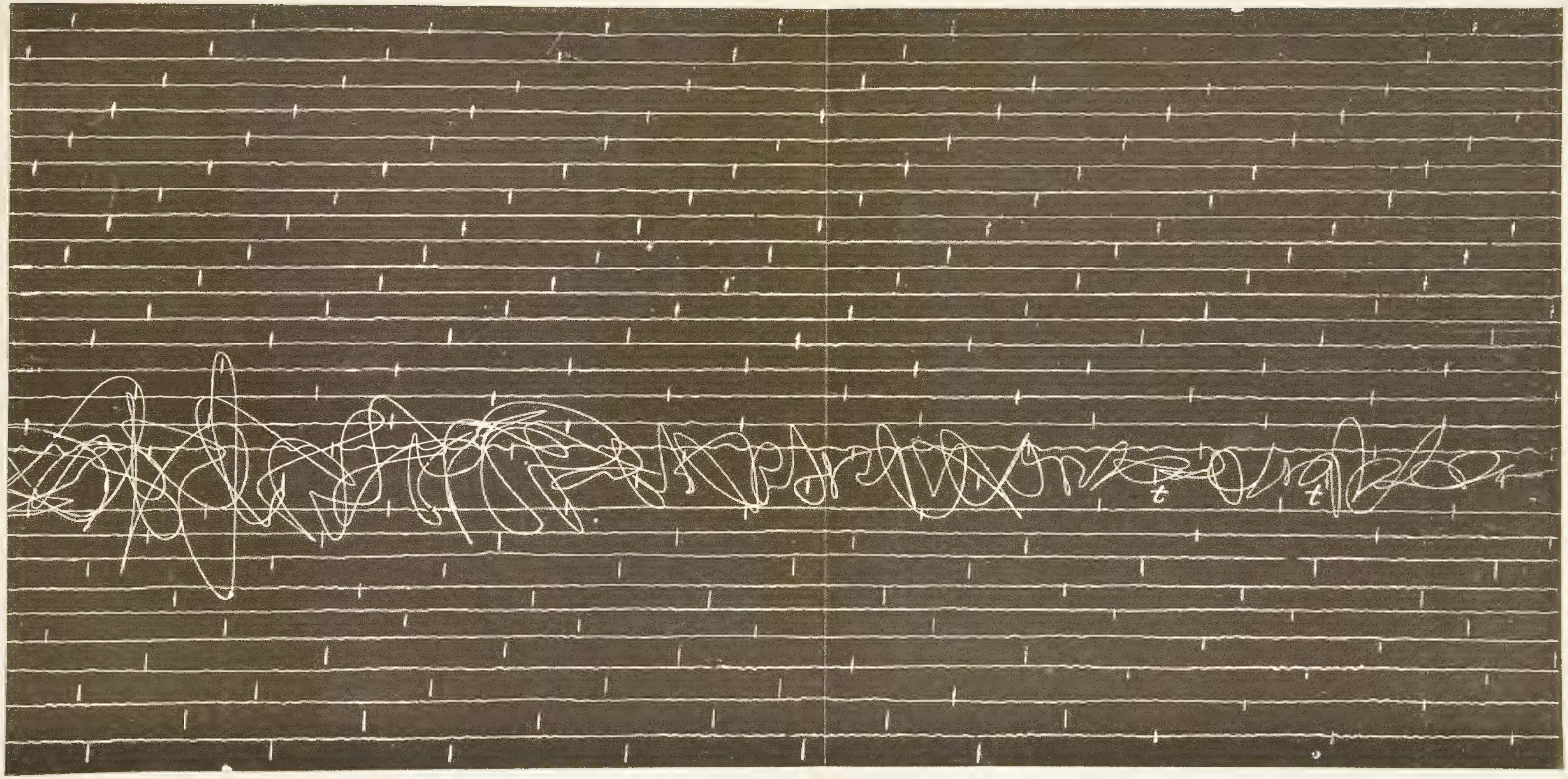
Fig. 2, B.

(Fig. 2, B is continued from Fig. 2, A.)

t......Successive minute marks.

Pl. LXXXIX, B.



a......Preliminary Tremor, composed of the longitudinal wave.

b......Commencement of the Principal Portion, at first composed of the transverse wave, but subsequently composed of the longitudinal wave.

Tokyification = 10), at Hongo.
gnification = 20), at Hongo.
fication = 30), at Hitotsubashi.
fication = 20), at Hongo.

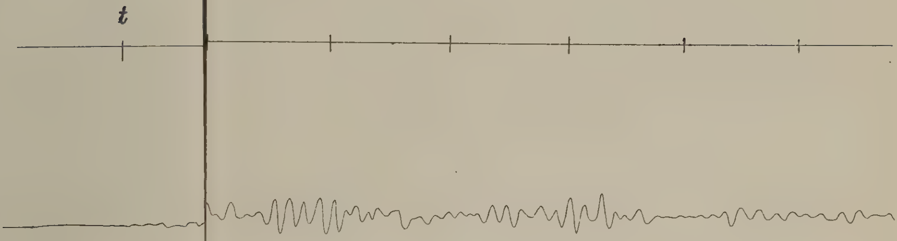


Fig. 3.

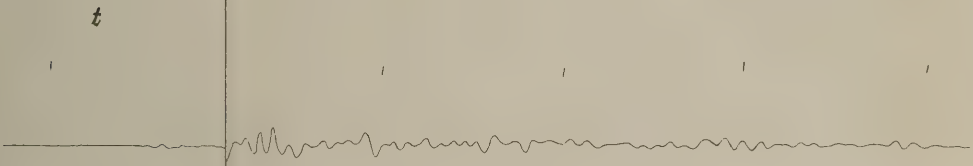


Fig. 4.

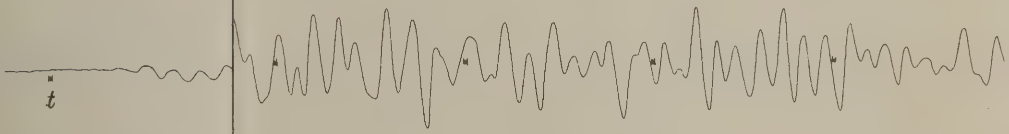


Fig. 5.

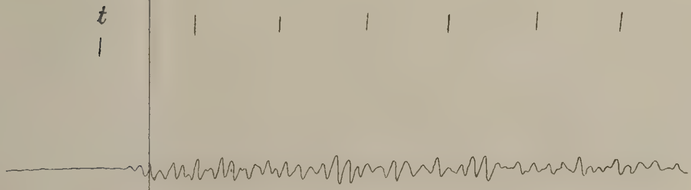


Fig. 5′.

o and Hitotsubashi.

Tokyo Observation of the Sakura-jima earthquake of Jan. 12, 1914, at 6. 28 P. M.

(1 Time Mark Interval = 1 minute.)

Fig. 3. E.W. Component (magnification = 10), at Hongo.
Fig. 4. Vertical Component (magnification = 20), at Hongo.
Fig. 5. N.S. Component (magnification = 30), at Hitotsubashi.
Fig. 5′. N.S. Component (magnification = 20), at Hongo.

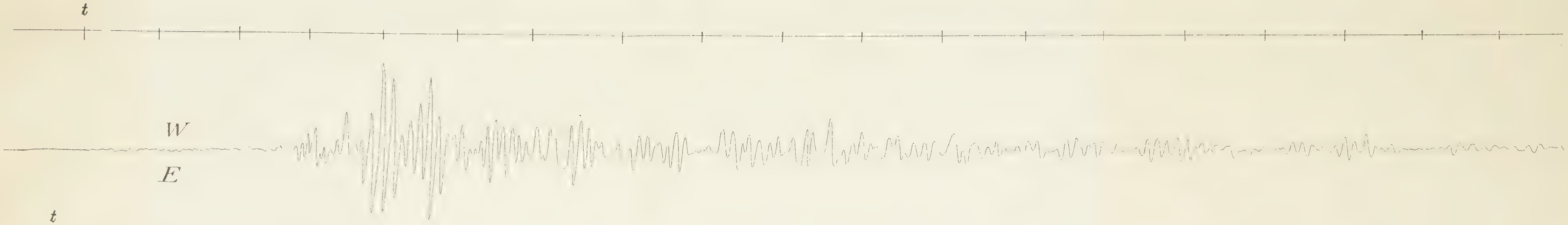


Fig. 3.

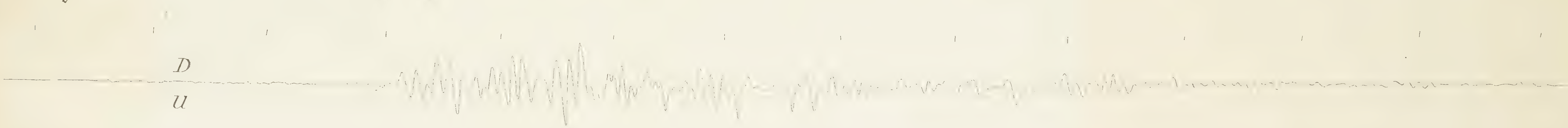


Fig. 4.

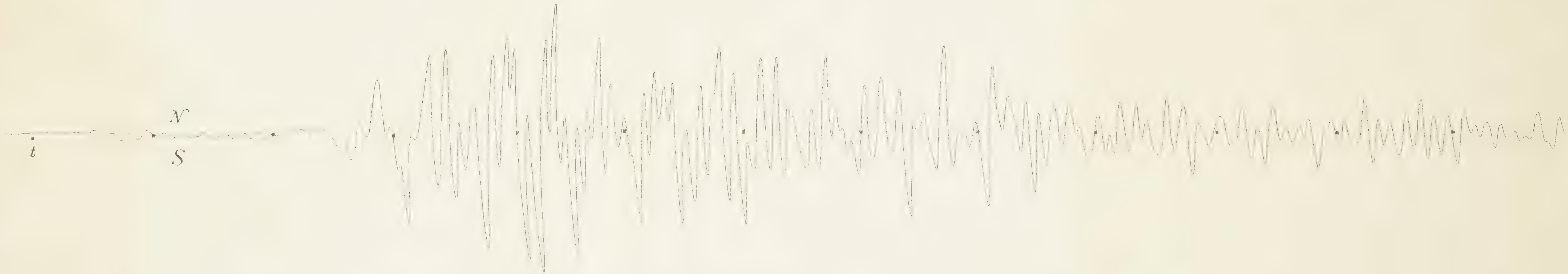


Fig. 5.

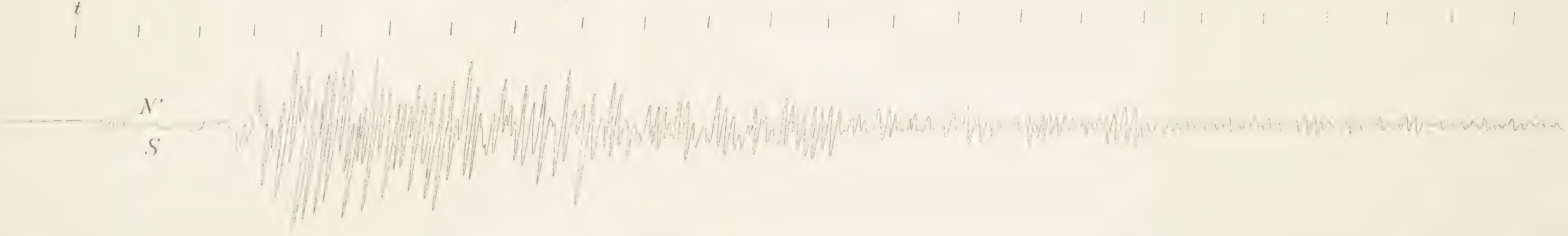


Fig. 5′.

Figs. 5. and 5.′ The individual vibrations can be identified in the diagrams obtained at the two different stations of Hongo and Hitotsubashi.

Itoshima (糸嶋) earthquake of 1898 in the western part of the province of Chikzen (Kyushu).

4. Focal Depth of the Destructive Sakura-jima Earthquake. The origin of the destructive earthquake on Jan. 12, 1914, at 6½ P.M., was probably situated in the Kagoshima channel, between the former islet of Karasu-jima and the coast of the city of Kagoshima, at about 4 km. to the S.E. of the Kagoshima meteorological observatory, say, at $\varphi = 31° 35'$ N., $\lambda = 130°$ $35'$ E. According to the seismographical registers at the latter, the duration of the preliminary tremor of the fore-shocks was on the average 1.9 sec., while that of the aftershocks was found also to be practically identical, namely, 1.94 sec. (See this Volume, No. 5.) The duration of the preliminary tremor of the destructive earthquake may probably, without a sensible error, be taken to be 1.9 sec., which according to my calculation formula given in the Bulletin, Vol. IX, No. 1, corresponds approximately to the central distance of 14 km. This is to be regarded as denoting, not the surface radial distance from the epi-centre, but the direct distance between the place of observation and the seismic focus or centre; the formula here utilized being, for the shorter distances, based on the observations of the earthquake motion caused by the explosions of the Asama-yama volcano, for which the source of disturbance lay at the surface itself. The focal depth is found to be about 13 km. (See fig. 6.)

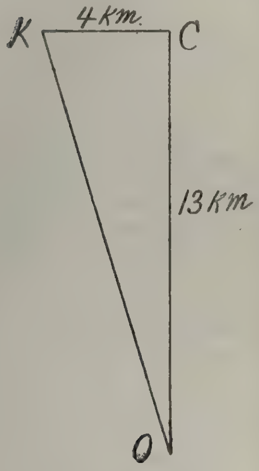


Fig. 6.

O……Eqke. Focus
C……Epicentre.
K……Kagoshima Met. Observatory.

The destructive earthquake in question took place during the explosive phase of the volcanic outburst of Sakura-jima, about four hours before its intensity culmination, and some 24 hours before the commencement of the lava outflow. The earthquake was, therefore, probably caused by the strong underground expansive volcanic force, which must have imparted an initial upward impulsive motion to the district in the epifocal area, as is verified by the seismographical record at Kagoshima. (See this Volume, No. 5, Pl. LXXVII.)

5. Seismic Damage in Kagoshima. The damage in the city of Kagoshima due to the strong earthquake on Jan. 12, at 6. 28 P.M. was, according to the report of the prefectural office, as follows :—

Killed	8 men and 4 women (including 3 wounded who subsequently died).
Wounded	15 men and 12 women.
Horses and cattle	24 killed.
Buildings	39 totally collapsed*; 130 half collapsed; 977 partially damaged.
Boats	13 totally wrecked, 22 partially damaged.
Roads	Damaged at 12 places, total area 383 *tsubo*.†
Bridges	5 damaged.
Stone wall	Damaged at 675 places, total area 6,265 *tsubo*.†
Board fences	Damaged at 110 places.

Table II., communicated by the Police Office of Kagoshima, gives the numbers of the buildings* totally or partially destroyed in the different streets of the city, by the strong earthquake at 6. 28 P.M. on the 12th. The total amount of the damage was as follows :—

	Number of the dwelling houses.	Nnmber of the ware houses, etc.
Totally destroyed,	29	86
Partially destroyed,	117	181
Slightly damaged,	9,405	1,055

Thus only about 0.2 % of the total number of the dwelling houses in the city have been overthrown by the shock. The greatest amount of destruction occurred naturally in the made grounds and the strand streets, such as Kasuga-cho (春日町), Yanagi-machi (柳町), Sumi-cho (須美町), Ogawa-machi (小川町), Kinsei-cho (金生町), Daikok-cho (大黑町), Izumi-cho (泉町), Shiomi-cho (汐見町), Seisan-cho (生產町), Naka-machi (中町), Gofuk-cho (吳服町), and Higashi-Sengok-cho (東千石町), at the sea coast portions of the old city quarters to the north of the Kotsuki-gawa ; and Tokiwa-cho (常盤町), Take (武町), Korai-cho, (高麗町), Kamino-sono (上ノ園), and Arata-machi (荒田町), in the newer portions of the city to the south of the same river.

---

* In the official estimates the number of the buildings totally destroyed often includes those standing whose damage is so heavy as to necessitate a rebuilding.

† 1 *tsubo*=36 sq. *shaku*=36 sq. feet nearly.

Table II. Damage to Buildings in the City of Kagoshima caused by Strong Earthquake of Jan. 12, 1914.

Street.	町　名	Total Number of Houses.	Dwelling Houses.				Ware Houses, etc.			
			Total Collapse.	Half Collapse.	Slight Damage.	Sum.	Total Collapse.	Half Collapse.	Slight Damage.	Sum.
Tsuzumigawa.	鼓川	147	—	1	131	132	3	5	30	38
Inari.	稲荷	179	—	1	144	145	2	8	56	66
Shimizu.	清水	296	—	—	212	212	3	10	71	84
Kasuga.	春日	216	—	2	215	217	3	2	30	35
Takashi.	鷹師	171	—	—	163	163	—	—	9	9
Yakushi.	藥師	171	—	—	154	154	5	1	2	8
Nishida.	西田	432	—	2	384	386	3	3	23	29
Shinyashiki.	新屋敷	377	—	—	170	170	—	—	35	35
Tokiwa.	常盤	222	1	—	218	219	1	1	1	3
Take.	武	167	—	—	173	173	—	7	—	7
Korai.	高麗	303	—	—	361	361	—	1	7	8
Kaminosono.	上ノ園	231	—	4	232	236	1	2	4	7
Kami-Arata.	上荒田	268	—	—	352	352	1	5	4	10
Shimo-Arata.	下荒田	639	1	4	742	747	4	—	4	8
Shimo-Tatsuo.	下龍尾	294	—	6	210	216	14	12	44	70
Kami-Tatsuo.	上龍尾	280	2	4	208	214	4	14	48	66
Ikenoue.	池ノ上	241	—	6	181	187	1	14	56	71
Yamashita.	山下	681	3	2	408	413	—	5	51	56
Yasui.	易居	319	2	1	237	240	7	2	12	21
Seisan.	生産	63	1	—	54	55	3	—	11	14
Muika.	六日	66	3	2	25	30	—	—	4	4
Tsuki.	築	46	1	—	23	24	3	6	5	14
Shin.	新	211	—	3	102	105	—	—	20	20
Horie.	堀江	285	—	1	180	181	—	—	30	30
Matsubara.	松原	466	—	5	98	103	—	—	25	25
Izumi.	泉	162	1	—	166	167	—	1	35	36

Table II. Damage to Buildings in the City of Kagoshima caused by Strong Earthquake of Jan. 12, 1914. (*Cont.*)

Street.	町名	Total Number of Houses.	Dwelling Houses.				Ware Houses, etc.			
			Total Collapse.	Half Collapse.	Slight Damage.	Sum.	Total Collapse.	Half Collapse.	Slight Damage.	Sum.
Shiomi.	汐見	65	—	—	110	110	1	1	36	38
Sumiyoshi. . . .	住吉	183	1	5	150	156	2	3	40	45
Susaki.	洲崎	30	3	—	20	23	1	2	10	13
Higashi-Sengok.	東千石	460	—	6	425	431	7	3	15	25
Naka.	中	160	1	13	136	150	1	15	17	33
Kinsei.	金生	112	2	3	110	115	1	15	38	54
Funats.	船津	164	—	—	113	113	5	3	15	23
Daikok.	大黒	177	2	15	182	199	1	5	12	18
Gofuku.	呉服	119	1	8	97	106	—	15	22	37
Yamanokuchi. .	山ノ口	548	—	6	262	268	4	7	44	55
Hinokuchi. . .	樋ノ口	554	—	—	270	270	—	—	45	45
Kajiya.	加治屋	426	—	—	216	216	—	—	41	41
Sonta.	草牟田	307	—	—	198	198	—	—	12	12
Shinshoin. . . .	新照院	273	—	—	117	117	—	—	7	7
Nishi-Sengok. .	西千石	472	—	—	229	229	—	—	13	13
Hiranomachi. .	平之町	463	—	—	200	200	—	—	11	11
Shioya.	鹽屋	633	2	10	340	352	1	1	35	37
Ogawa.	小川	178	2	3	150	155	2	5	15	22
Ebis.	惠美須	148	—	—	130	130	—	1	1	2
Izumiya.	和泉屋	112	—	—	55	55	—	—	3	3
Kruma.	車	141	—	—	85	85	1	—	5	6
Yanagi.	柳	147	—	2	145	147	—	4	—	4
Mkaie.	向江	28	—	2	16	18	—	—	—	—
Sakai.	榮	62	—	—	30	30	1	—	1	2
Nagata.	長田	322	—	—	56	56	—	2	—	2
Reisui.	冷水	172	—	—	20	20	—	—	—	—
Sum.	合計	13,389	29	117	9,405	9,551	86	181	1,055	1,322

(F. Omori, phot.)

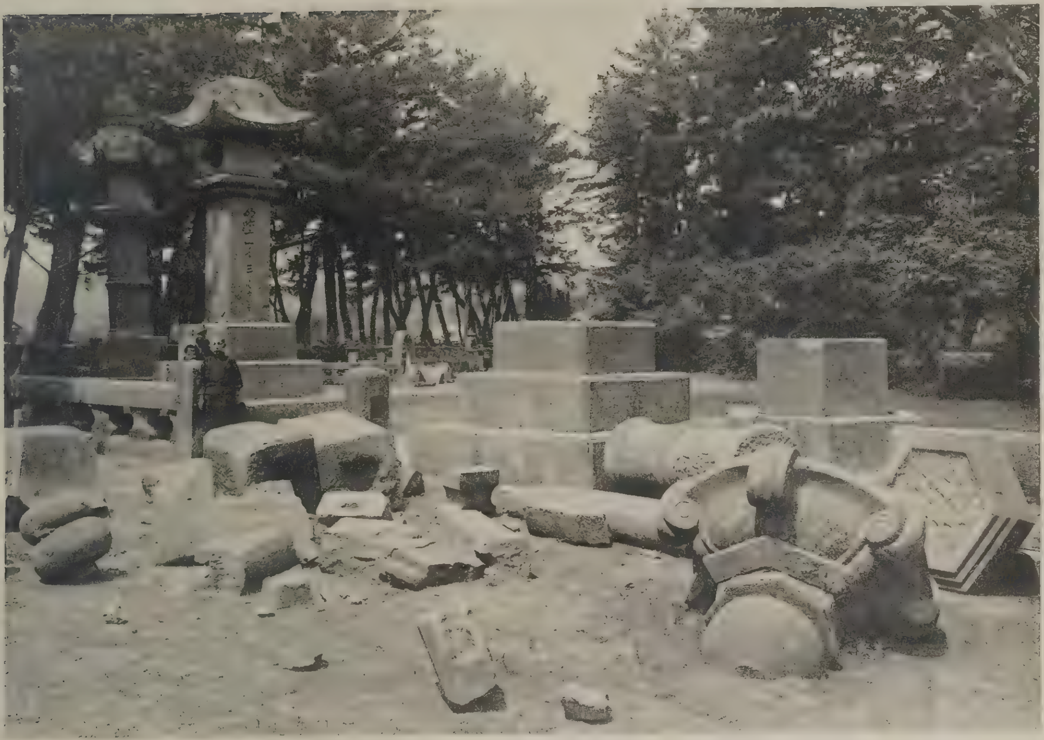


Fig. 7. Large overturned Stone Lanterns at Gion-no-su, in the northern part of Kagoshima.

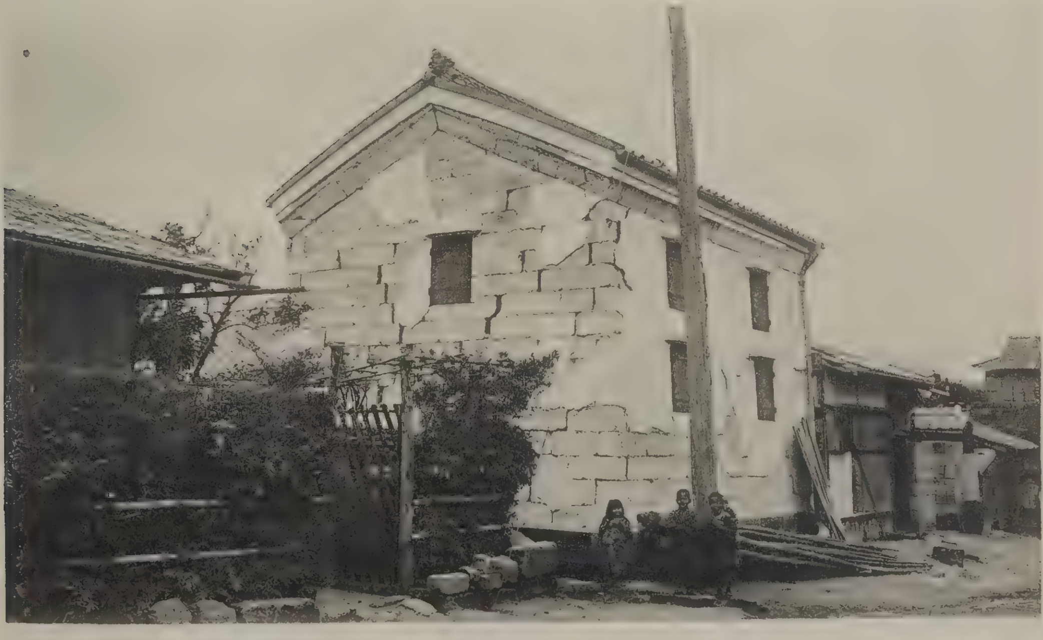


Fig. 8. A Stone Ware-house, in northern part of Kagoshima, badly cracked along mortar joints.

(F. Omori, phot.)

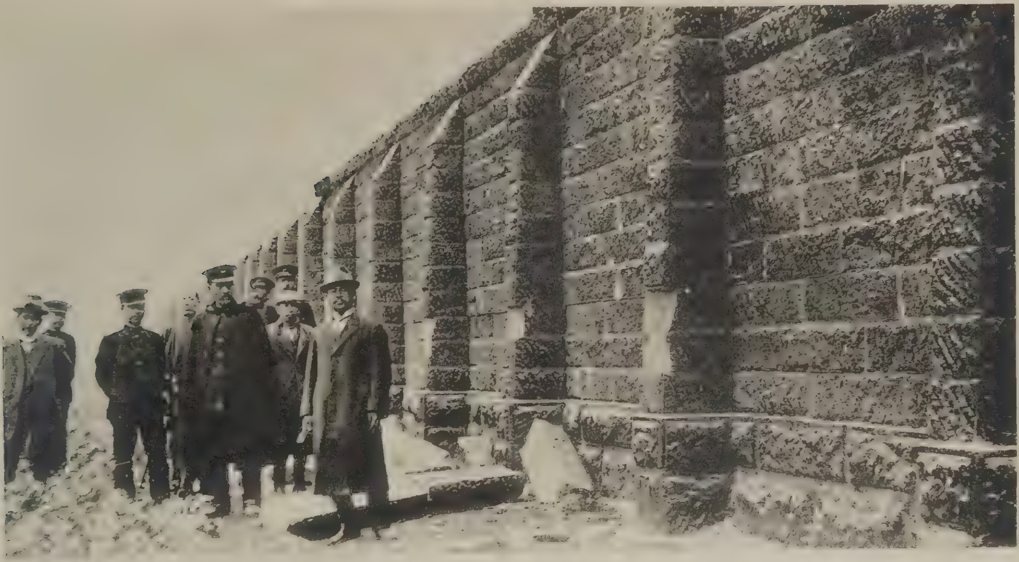


Fig. 9. Stone Fence Wall of the Kagoshima Prison. Stones below the horizontal crack line scratched off.

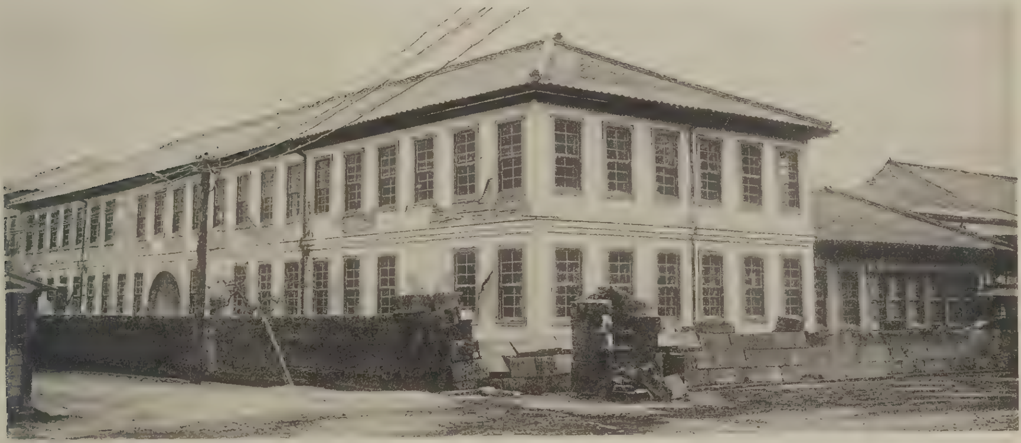


Fig. 10. Part of the Prefectural Buildings: The plasters on the E. and W. longer sides were much cracked and shaken down. The N. fence stone wall was partially overthrown.

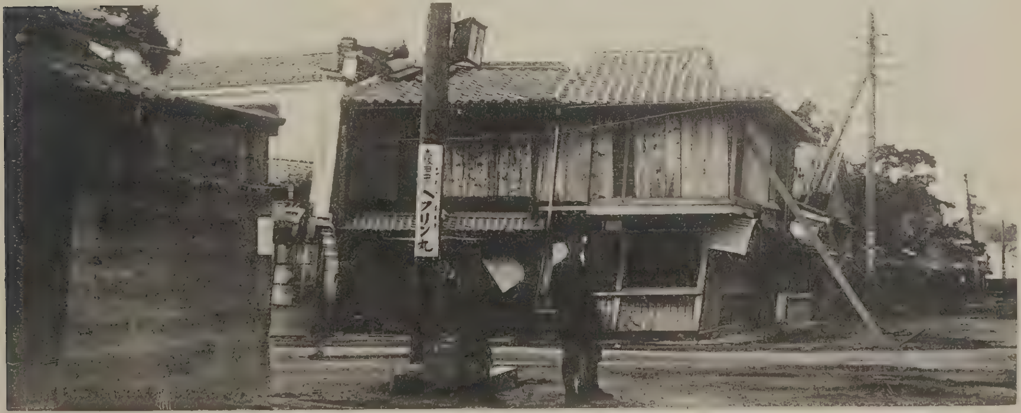


Fig. 11. An E. End House of a Row of Street Buildings parallel E. W. much thrown out of the vertical.

6. Stone Structures. The comparatively large amount of the seismic damage was due to the existence of the dwelling houses, ware-houses, retaining walls and fences made of the soft tuff-like andesite which came widely in use within the ten years preceding the eruption. The majority of these structures, which are very poorly mortared and little better than simple piles of the stone blocks, are much damaged by earthquake shocks, being seismically far weaker than ordinary brick buildings. Especially the fence walls proved very dangerous, as, being propped by buttresses on the inner side, where the ground is generally higher than on the outside street, these were overturned toward the latter quite easily. Of the 9 cases of the direct mortality in the city none was due to house collapse, all the victims having met their death on the street by the overthrowing of the stone fence walls. The building stones are chiefly of the following five species :—

(1)	Isousu-ishi (磯臼石)	Used in better class buildings and in stone bridges.
(2)	Ono-ishi (小野石)	Used in buildings.
(3)	Kajiki-ishi (加治木石)	,, ,,
(4)	Kogashira-ishi (河頭石)	,, better class buildings.
(5)	Iso-ishi (磯石)	,, stone fence walls.

Through the kindness of Mr. J. Oi, chief of the public works department of the Kagoshima prefecture, I have procured 8 specimens of the stones of the species (1), (2), (4) and (5), out of which 81 test pieces were formed. According to the results of the testing, (Table III), the Iso-ishi (5) were found to be very weak, the tensile strength being about 70 lbs. per sq. inch. Even of the hardest Isousu-ishi the tensile strength did not exceed 228 lbs. per sq. inch.

石 材	Stone Specimen.	Density.	Ultimate Tensile Strength. (lbs. per sq. in.)
磯 石 (軟 質)	Iso-ishi (soft).	—	70
,, ,,	,, (,,).	—	73
,, (硬 質)	,, (hard).	2.03	123
小 野 石	Ono-ishi	—	150
,,	,,	2.00	221
加 治 木 石	Kajiki-ishi.	—	155
河 頭 石	Kogashira-ishi.	2.34	172
磯 臼 石	Isousu-ishi.	2.12	228

It is needless to add that the different stone species in question can be used, with proper mortar and under adequate design, as good building material for earthquake-proof structures. Thus, the one story stone buildings of the Kagoshima Prison have sustained no seismic damage.

I reproduce below the results obtained by Dr. S. Uchida, of the Architecture Department, in connection with the building stones used in Kagoshima.

Stone Specimen.		Weight per cubic foot, (in lbs.).	Ultimate Strength (in lbs. per sq. in.), against		
			Crushing.	Stretching.	Cross Breaking.
河頭石	Kogashira-ishi.	146	7180	276	565
硬質礫石	Isc-ishi (hard).	133	4910	—	729
軟質礫石	Iso-ishi (soft).	114	1460	—	—
小野石	Ono-ishi.	108	2590	—	—
加治木石	Kajiki-ishi.	106	2180	133	545

I mention here two cases of fracture of the small stone columns. At the

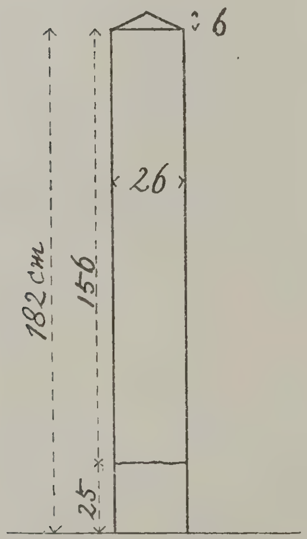


Fig. 12. Broken Stone Monument at the Terukni Shrine, Kagoshima.

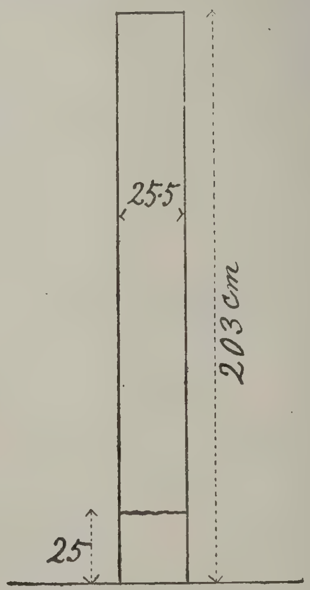


Fig. 13. Broken Stone Gate Post of the Kagoshima Meteorological Observatory.

Terukni shrine (照國神社), a stone monument, 26 cm. square in section, and 188 cm. in height (fig. 12), was broken at 25 cm. height from base. The intensity ($=\alpha$) of motion neccesary for producing the fracture* in question is, assuming the tensile strength to be 50 lbs. per sq. inch, found to be equal to an acceleration of about 5990 mm./sec^2.

Again, of the two similar stone gate posts (fig. 13) of the meteorological observatory, situated on the hill to the N. W. of Kagoshima, one remained uninjured, while the other was broken at the height of 25 cm. from base; the posts being each 203 cm. in height and 25.5 × 27.5 cm. in section. The seismic stability is, assuming the tensile strength to be 50 lbs. per sq. inch, found to be equal to an acceleration of 4630 mm./sec^2.

The seismic stability of each of these columns was thus sufficiently great and must certainly have been much higher than the actual intensity of the earthquake motion concerned. It is likely that the columns were broken near the base where some weak points or cracks had existed.

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* For the calculation of the seismic stability of columns, see the Publications of the Imp. Earthq. Inv. Comm., No. 4.

Table III. Tensile Strength of the Various Building Stones used in Kagoshima.

(Measured by F. Omori.)

磯　石 Iso-ishi.	磯　石 Isc-ishi.	小野石 Ono-ishi.	加治木石 Kajiki-ishi.
No. 1 Specimen.*	No. 2 Specimen.	No. 4 Specimen.	No. 6 Specimen.
97.2	93.9		173.3
96.9	93.3	189.5	172.9
76.7	88.1	185.2	156.9
74.8	88.0	182.5	140.9
73.8	83.9	166.3	120.9
73.6	78.4	157.2	(Mean) **155.0**
71.4	74.1	150.0	
70.7	72.6	149.2	河頭石 Kogashira-ishi.
69.3	72.6	147.9	
68.8	69.9	144.8	No. 7 Specimen.
67.9	68.0	144.4	197
58.9	62.9	140.6	192
58.8	62.8	127.4	180
57.4	15.1	121.8	173
51.7	(Mean) **73.1**	100.0	170
51.6		(Mean) **150.4**	166
(Mean) **69.5**			159
	No. 3 Specimen.	No. 5 Specimen.	141
	159	248	(Mean) **172**
	145	245	
	134	234	磯臼石 Isoüsu-ishi.
	125	232	
	115	230	No. 8 Specimen.
	115	212	268
	98	211	238
	91	159	230
	(Mean) **123**	(M an) **221**	221
			213
			199
			(Mean) **228**

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* Gate post of the Kagoshima Met. Observatory.

7. Direction of Motion in Kagoshima. In the city of Kagoshima numerous stone lanterns and tomb stones were overturned. (See fig. 7.) These being small columns generally not cemented to the pedestal, and of heights under 2 metres, with, in the case of the former, stems square or circular in section, serve as a simple sort of standing column seismometer and give indications of the direction of the maximum earthquake motion. The observations of the overturned bodies, mentioned below, have been made in the following different places:—Terukni Shrine, West Honganji, Nanrinji, Fukshoji, etc., in the central and southern parts of the city; the military cemetery, Jokomyoji, Tanoura, etc., in the northern part.

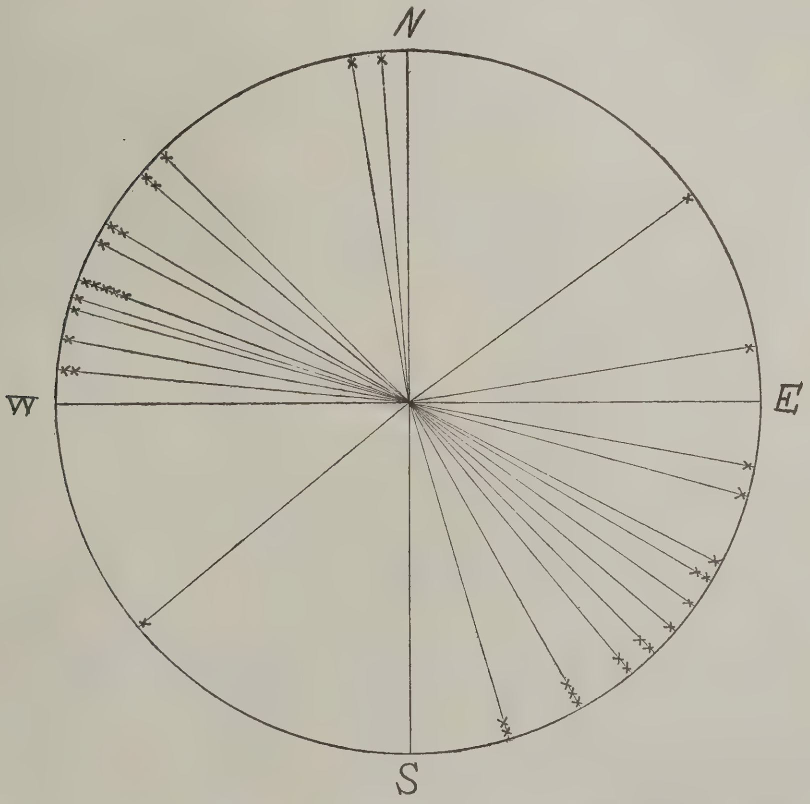

Fig. 14. **Diagram showing the Overturning Directions in the Northern Part of Kagoshima.**
Each small cross (×) indicates a monument or stone lantern overthrown in the direction of the radius on which it lies.

Terukni-jinsha (照國神社):—A slender square stone column was broken at base and overthrown towards N. 30°W. The kurin, or high nine-ring post projecting above the top roof, of the 5-story stupa (pagoda), inclined toward S.80°E. A square stem stone lantern was overthrown toward S.46°E. At Yamashitacho (山下町) a gate post, 1 × 1 shaku in size and 9 shaku in height, was thrown toward S.40°E.

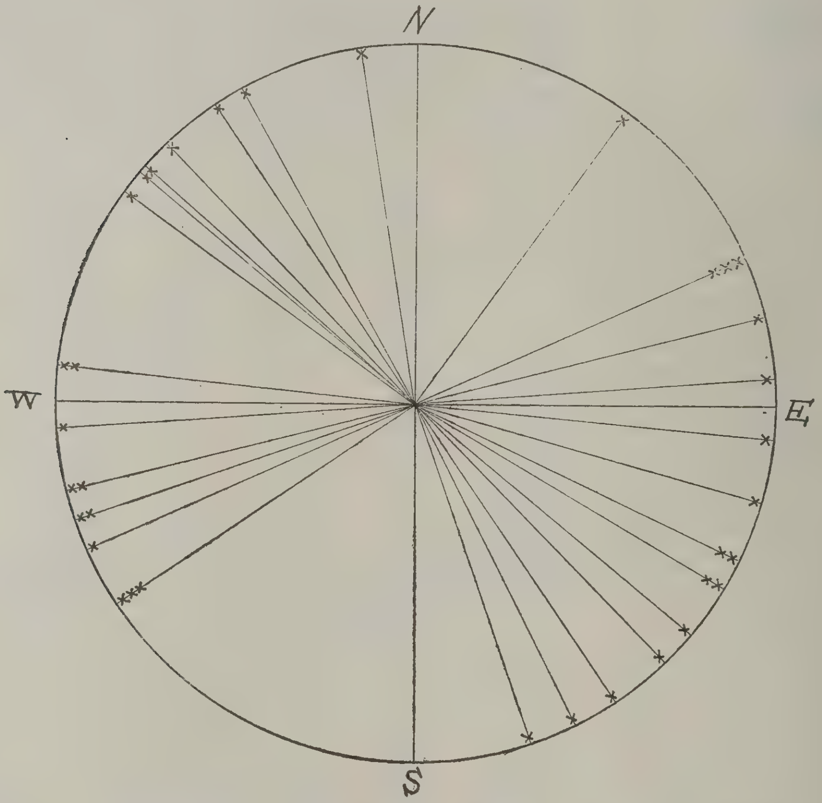

Fig. 15. Diagram showing the Overturning Directions in the Southern Part of Kagoshima. Each small cross (×) indicates a monument or stone lantern overthrown in the direction of the radius on which it lies.

West Honganji Temple :—The top of a large square-stem stone lantern was thrown toward S.55°E.

Btokukai (武德會):—Two square stone gate posts were overthrown toward S.60°E. and toward N.80°W.

Iwasaki Saw Mill :—The factory building was overthrown eastward.

Nanrinji (南林寺):—The monument for the victims of the Sakura-jima eruption of 1779, facing S.55°E., was thrown toward the latter direction.

Cylinder stem stone lanterns overthrown toward	
N.70°E.	N.80°W.
N.70°E.	S.80°W.
N.46°W.	S.70°W.
N.40°W.	S.60°E.

Square-section tomb stones overturned toward		
N.40°E.	N.25°W.	S.75°W.
N.80°E.	N.45°W.	S.15°E.
N.70°E.	S.30°E.	S.80°W.
N.5°W.	S.60°W.	S.60°W.
N.50°W.	S.75°W.	S.60°W.
W.		

Fkushoji (福祥寺):—An octagonal stem stone lantern was overturned toward S.70°E. The top of a cylinder stem stone lantern was thrown toward S.40°E.

One of the two stone gate posts of the Kagoshima Meteorological Observatory, 27.5 × 25.5 cm. in section and 203 cm. in height, was broken at 25 cm. from base and thrown toward the N.55°W.

Military Cemetery:—Numerous stone lanterns and tomb stone were overturned.

Square stem stone lantern overturned toward	
N.65°W.	N.65°W.
N.80°W.	N.70°W.
N.80°W.	N.85°E.
N.40°W.	S.35°E.
N.65°W.	S.75°E.

Square section tomb stone overturned toward	
S.45°E.	N.45°W.
S.70°E.	N.75°W.
N.55°W.	N.65°W.
N.58°W.	N.68°W.
N.65°W.	N. 5°W.

Fort Ground:—Square section tomb stones were overturned mostly toward N.58°E. A stone lantern with cylinder stem was overturned toward S.58°E. Another with square stem was overturned toward S.25°E.

Jokomyoji (淨光明寺):—Several large stone lanterns and monuments dedicated to the successive ancestral lords of the princely family of Shimazu were overthrown.

Square stem stone lanterns overturned toward	
S.25°E.	S.35°E.
S.50°E.	N.45°W.
S.40°E,	

Square section tomb stones overturned toward	
S.12°E.	S.40°E.
S.12°E.	S.55°W.
S.55°E.	N.

Summary. The directions of overturning given above refer to the magnetic north and south. Making the declination correction of 5° west, the 36 observations made at the military grave-yard, the Jokomyoji temple, and other places in the northern part of Kagoshima give the mean result of

N.61°W–S.61°E. The remaining 36 observations at Nanrinji and other places in the southern part of the city give the mean direction of N.76°W–S.76°E. (See figs. 14 and 15.) It will be observed that the overturning direction, which indicated the direction of the strongest motion in the northern part of the city was approximately identical with that of the vibration at the commencement of the earthquake as shown by the ordinary seismograph diagram obtained at the Kagoshima meteorological observatory. (See this Volume, No. V.).

At Tanoura (田ノ浦):—Two large stone lanterns (fig. 7) were not overturned, while two others exactly like these standing nearby were overturned respectively toward S.55°E. and S.25°E. For one of these, with the stem 59 cm. (=2x) square in section, the height (=y) of the centre of gravity is found to be 170 cm. The intensity or acceleration ($=\alpha$) of the earthquake motion necessary for overturning the structure regarded as a "small body," would be $\alpha=\frac{x}{y}\times g=1690$ mm./sec.^{2}, g being the acceleration due to the gravity. These stone lanterns, with the base dimension of nearly 2 feet, are, however, to be regarded rather as belonging to the category of "large body," and the range (=2a) of the earthquake motion necessary for the overturning would be some 37 cm., according to the equation: $2a=\frac{h}{y}\times x$, in which h (=214 cm.) is the height of the centre of percussion of the whole column with respect to the ground surface.

The mean direction of the maximum earthquake motion in the different parts of Kagoshima taken together was N.68°W.–S.68°E. This direction is probably habitual to the Kagoshima district and is almost exactly normal to the extension of the Kirishima, Sakura-jima and Kaimon-dake volcanic chain.

In the case of the Tokyo district, the maximum motion in the stronger earthquakes is generally executed in an E.–W. direction irrespective of the position of the seismic origin; the usual type of the maximum vibration which occurs at the commencement of the principal portion, consisting of an eastward displacement (single amplitude) followed by the counter westward displacement (double amplitude). Amongst the others, in the semi-destructive earthquake of June 20, 1894, the maximum displacement was directed toward the S.71°W. The prevailing direction in the earthquakes disturbing the Tokyo district, or the Kwanto provinces at large is normal to the course of the Fuji volcanic chain. It is conceivable that in a district situated not far distant from a volcanic chain the principal earthquake motion has the habit of taking place at right angles to the latter.

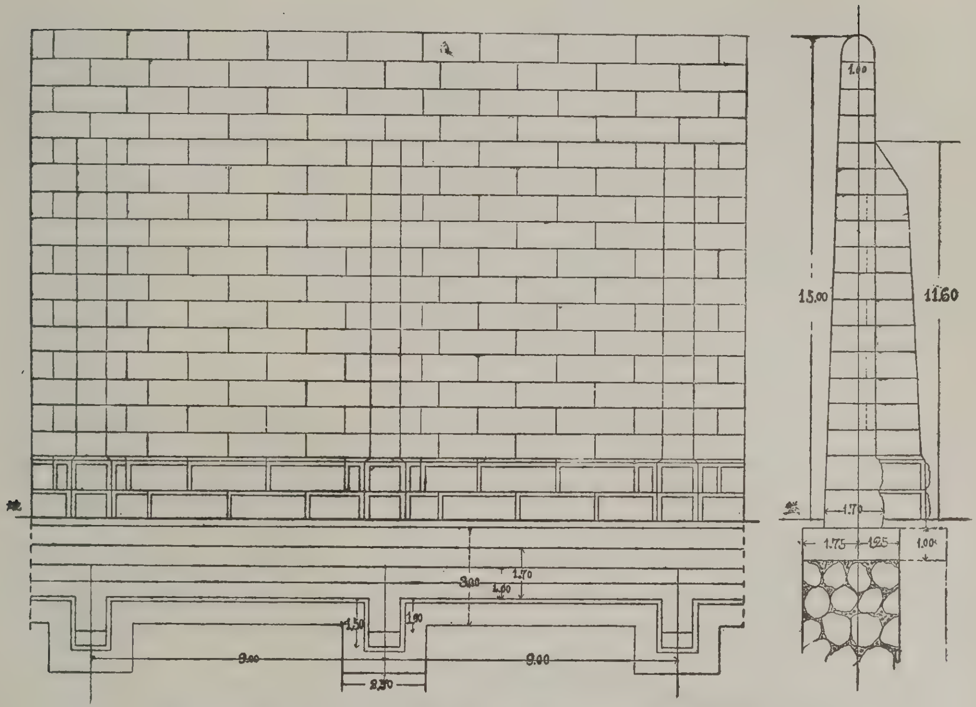

Fig. 16. Elevation, Plan, and Section of the Wall of the Kagoshima Prison.
Dimensions are given in *shaku.* (1 *shaku*=0.994 foot.)

8. Damage to Buildings and the Direction of Motion. The direction in Kagoshima of the maximum vibration of the destructive earthquake on Jan. 12, at 6. 28 P.M., was nearly E.–W. (See § 7). Consequently the seismic damage to the buildings, partitions and masonry walls were different according to directions. Thus, the walls running parallel N.–S. were overthrown, or tended to be overthrown, by being cracked at their bases. If not thus cracked, those walls remained intact. On the other hand, the walls in an E.W. direction were in very many cases damaged by being cracked obliquely in two systems of lines mutually normal and inclined at an angle of 45° to the base, sometimes resulting in the falling down of the broken pieces at the central portion. Fig. 10 illustrate the occurrence of the two different types of crack: the 2-story wooden building, part of the prefectural office, had its north and south side plastered walls much cracked and shaken down, while the east and west end walls were not damaged; the enclosure stone wall had, however, its east side partially overthrown, while the south side remained intact.

Fig. 9 shows the seismic damage done to the front, or east, side of the enclosure wall of the Kagoshima Prison. The wall, 15 feet in height and 1.7 feet in base thickness, (fig. 16), with buttresses on the outside at successive distances of 9 feet, was cracked near the base through the whole length; the parts of the buttresses just below the horizontal crack being in very many cases torn off and thrown down. This was the result, as is shown by the photograph, of a relatively outward motion of the portion of the wall above the plane of fracture. It seems thus likely that the first strong displacement, at the commencement of the principal portion of the earthquake, was directed westwards, or away from the Sakura-jima, while the counter and larger movement took place eastwards or toward the island.

Fig. 11 illustrates a case, in which the houses at the east end of a row of the shops along a street parallel west-east, were considerably pushed eastwards, a broken partition wall in the N.S. direction being also much inclined toward the same direction. Several of the high enclosure walls and slender partitions in the E.W. direction received no seismic damage.

9. Effect on Masonry Break-Water. The masonry breakwater protecting the Daimonguchi made-ground (大門口) to the south of the harbour of Kagoshima is 500 *ken* (=3000 *shaku**=909 metres) in length and extends almost exactly in the N.–S. direction, being normal to the corresponding radius proceeding from the centre of Sakura-jima. (See fig. 17.) It had been originally constructed between April 1901 and Jan. 1902, having received improvement repairs in 1904–1905. As will be seen from fig. 20, the structure is, notwithstanding its apparent solidity, in reality a sort of embankment with the coping 6 *shaku* in width and 17.5 *shaku* above the low water line, filled in with gravel and earth, and lined on the outside with a layer of stone blocks.

The strong earthquake of Jan. 12th produced no cracking or other apparent serious damage of the breakwater. A careful measurement made by the Public Works Department of the Kagoshima prefecture indicated, however, that the horizontality of the coping was deranged, the maximum amount or range of the relative elevation and depression along the whole length of 1340 *shaku* or 406 metres of the portion examined (figs. 18 and 19) being 0.145 *shaku* (=0.044 m.). The break-water, which was approximately normal to the direction of the maximum earthquake motion, underwent a far greater transverse deformation; the whole structure having been thrown out slightly in a curve form outwards, or toward the free east side, with the

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* 1 *shaku*, or Japanese foot, =0.994 English foot.

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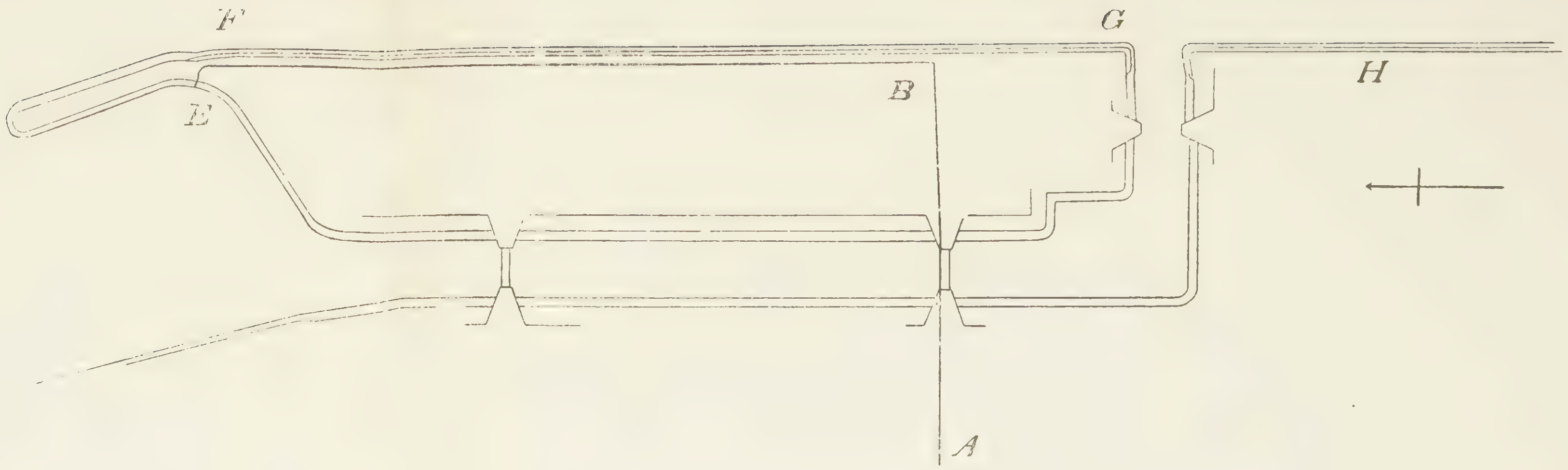
Fig. 17. Plan of the Masonry Breakwater and the Canal, of the Kagoshima Harbour.

FG, H......Breakwater Walls.

FG.......... ..Portion examined whose deformation is indicated in figs. 18 and 19.

ABE........ Oil Pipes.

(Scale: 1/4000.)



Earthquake Effect on the Masonry Breakwater of the Kagoshima Harbour.

(Length Scale: 1/1,400.)

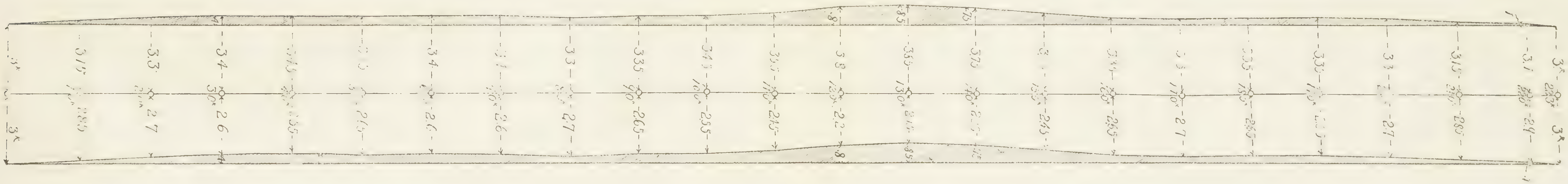


Fig. 18. Plan of the Breakwater, showing the Lateral Deformation. (Tansverse Scale: 1/70.)

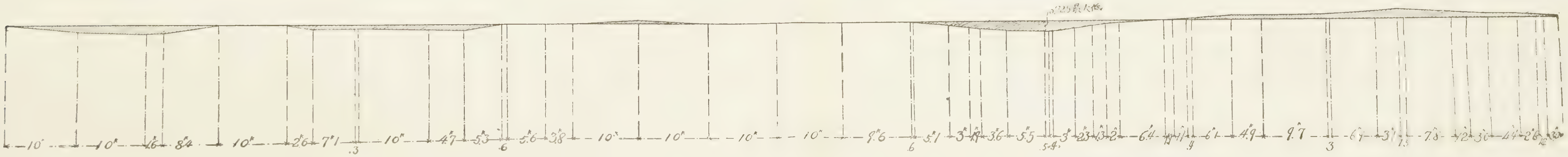


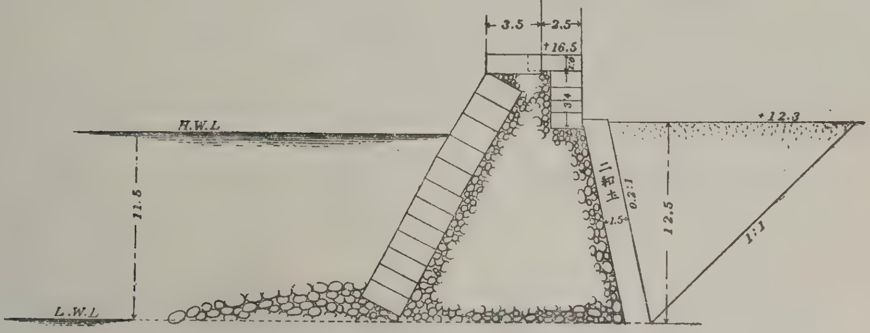
Fig. 19. Vertical Deformation of the Top Surface of the Breakwater. (Vertical Scale: 1/12.)

Length, in *ken* (1 *ken* = 6 *shaku*).

Width and Height, in *shaku* (1 *shaku* = 0 994 foot).

maximum displacement of 0.85 *shaku*=0.26 metre near the middle of the length.

Fig. 20. • Section of the Breakwater of the Kagoshima Harbour.
Dimensions in foot.



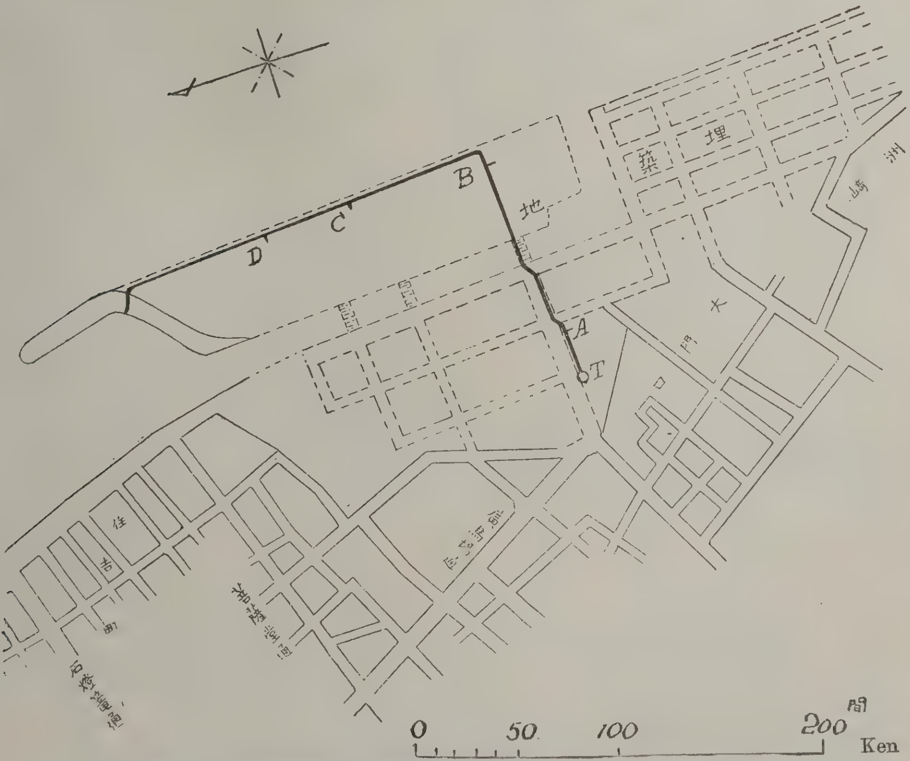
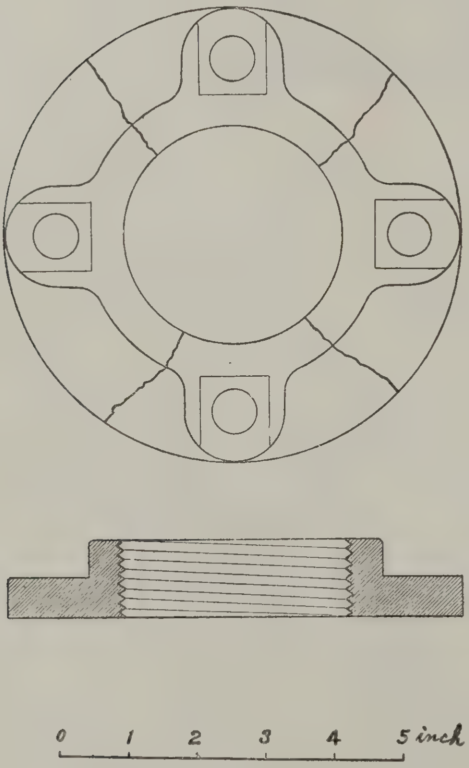


Fig. 21. Map showing the Location of the Oil Conducting Pipes (DBAT).
A, B, C, D.......Points of fracture of the pipe joints. T......Tank.
Dotted lines indicate the made grounds.

Beside the above-mentioned vertical and lateral relative deformations at different points along the length of the breakwater wall, the latter has also probably been bodily displaced, possibly through a range of some 1 foot normal to its length, as may be judged from the manner of the seismic damage done to the iron pipes laid in the immediate vicinity. (See below.)

10. Oil Pipes. For the conduction of petroleum there had been laid 3″ cast iron gas pipes at the depth of 2 feet, for the length of 1130 *shaku*=343 metres, on the made ground, parallel to and at the distance of 12 feet inside the breakwater wall above mentioned. At the south end the pipes are laid for the extension of 700 feet toward the west, across the made ground and the canal, to the New York Standard Oil Company's tank at Matsbara-machi (松原町). (See fig. 21.) In consequence of the softness of the made ground and especially of the movement of the breakwater wall, the iron tubes were broken by the earthquake shock at three places *B*, *C*, and *D* the damage occurring in each case at the screw-joint coupling. At *C* and *D*, near the middle of the N.-S. length, the broken tubes were torn apart respectively 3″ and 4″. At *B*, a short distance after the bending toward the west, the tubes were torn apart through the range of 13″, evidently due to the transversal bodily displacement of the wall. (See fig. 23.) At *A* (fig. 21) near the oil tank, a 3″ pipe was torn off at a joint, breaking the flange there into 4 pieces (fig. 22).

Fig. 22. Broken 3″ Gas-Pipe Flange Coupling.



11. Gas Pipes in the City of Kagoshima. The aggregate length of the main and subsidiary gas pipes existing in the city of Kagoshima at the time

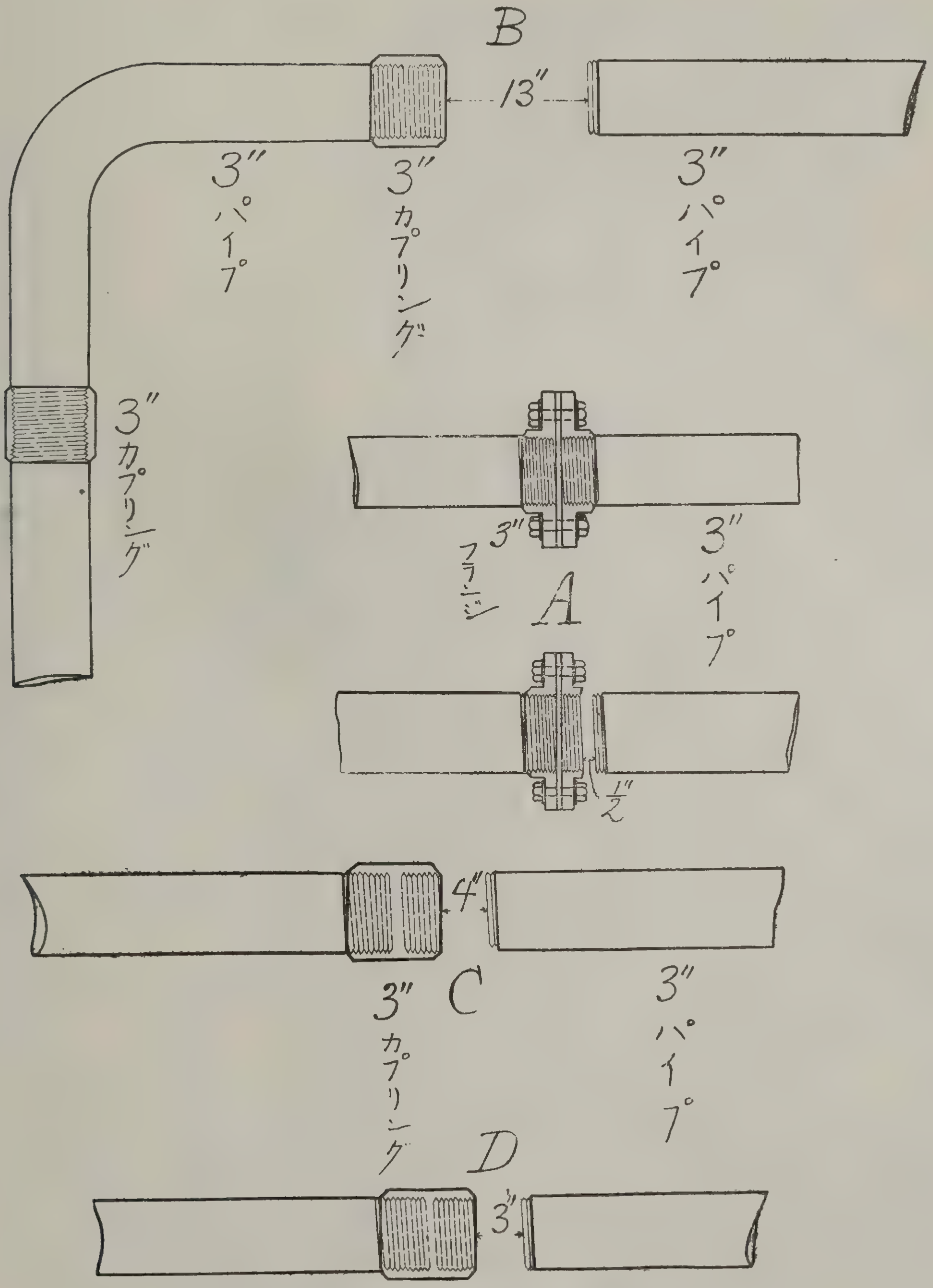


Fig. 23. Joint Fracture of the 3″ Oil Pipes.

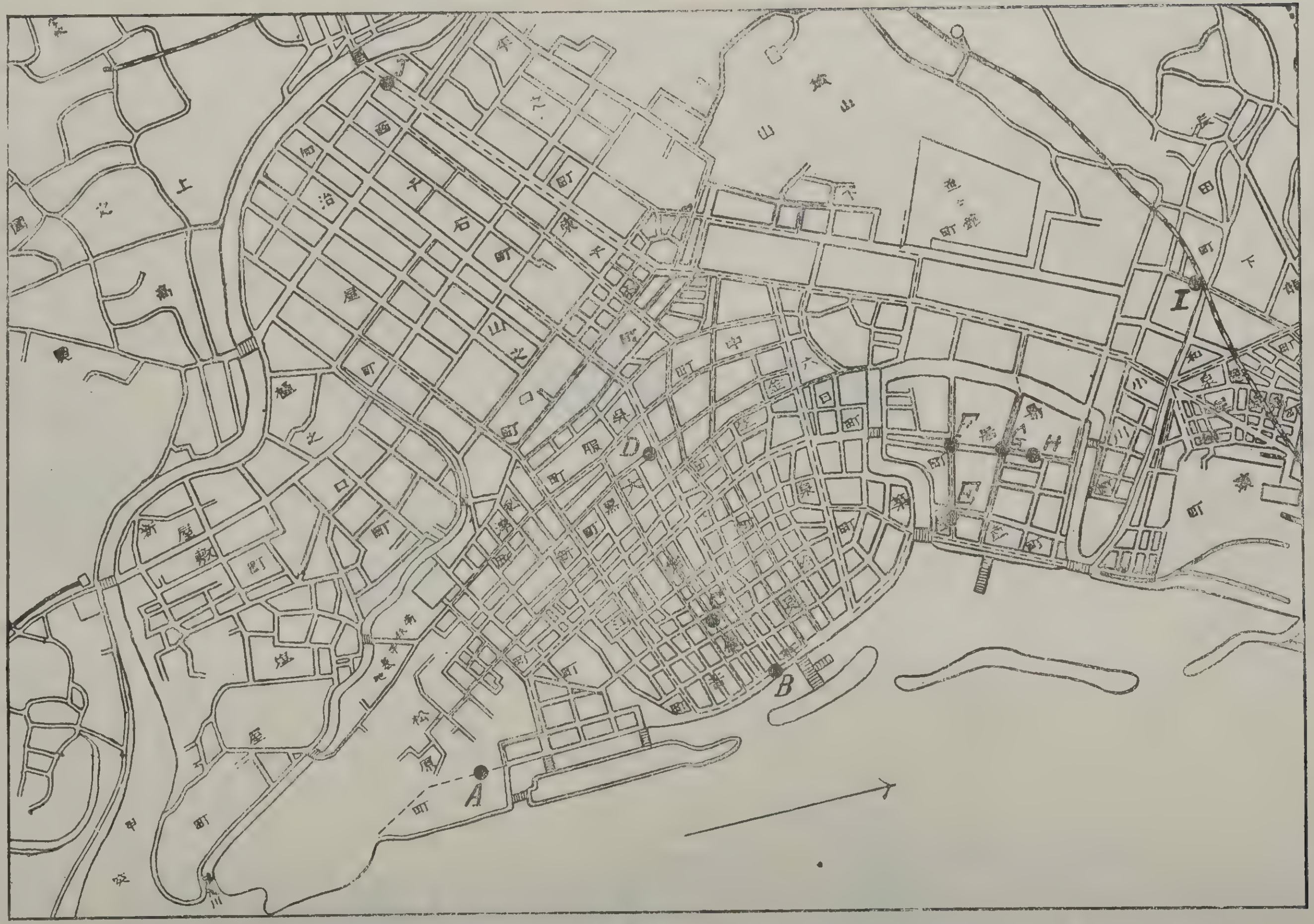


Fig. 24. Map of the City of Kagoshima, showing the Places (A, B, C......J) where the gas pipes were broken by the earthquake of Jan. 12, 1914. (Dotted lines indicate the location of the 2" to 8" gas pipes.)

of the Sakura-jima eruption of 1914 were respectively 47,394 and 88,126 *shaku*,* as follows :—

Main Pipe.	
8″ Diameter	6,261 *shaku*
6″ ,,	7,586
4″ ,,	7,764
3″ ,,	25,783
Sum	47,394

Subsidiary Pipe.	
2″ Diameter	11,500 *shaku*
1″½ ,,	7,564
1″¼ ,,	10,427
1″ ,,	12,790
¾″ ,,	42,027
½″ ,,	3,818
Sum	88,126

The main pipes were of cast iron, while the subsidiary pipes were mostly of wrought iron. There was no case of fracture or other serious damage done to the larger main pipes except at one place on the made ground near the south end of the Canal (運河) of the Kagoshima harbour, where an 8″ pipe was drawn out of socket together with the lead to the amount of 3″½. Cases of mere joint loosening were, however, numerous, especially along the 3″ and 6″ pipes on the Bosato-dori, one of the main streets of Kagoshima, which runs parallel east and west, namely, approximately in the direction of the strongest earthquake motion. In vicinity of the High School (造士館), there was a case of pulling out of a screw joint at the point of normal branching of 2″ wrought iron pipes from the line, the 6″ pipes laid along the Yakata-baba street running in a N.N.E.–S.S.W. direction.

Damage to the wrought iron pipes of 1″ to 2″ diameters, which was confined to screw joints, took place in nine cases, as follows :—

Locality.	Direction of Street.	Position indicated id Fig. 24.	Size and material of Coupling.
Smiyoshi-cho (住吉町).	N.–S.	B	2″ Cast iron.
Yasui-cho (易居町).	W.N.W.-E.S.E.	F	2″ ,,
,,	,,	E	2″ Wrought iron.
Kruma-cho (車町).	N.E.-S.W.	I	1″½ Cast iron.
———	———	—	1″½ ,,
Smiyoshi-cho (住吉町).	W.S.W.–E.N.E.	C	1″½ Wrought iron.
Yasui-cho (易居町).	W.N.W.–E.S.E.	D	1″¼ Cast iron.
Konaya-dori (小納屋通).	N.–S.	G	1″¼ Wrought iron.
Yasui-cho (易居町).	N.E.N.–S.W.S.	H	1″ ,,

---

* 1 *shaku*=1 metre/3.3 = 0.994 English foot.

Cast-iron Gas-pipe broken in Wrought Iron Socket.

(×)........Broken End of Gas-pipe.

Fig. 25.

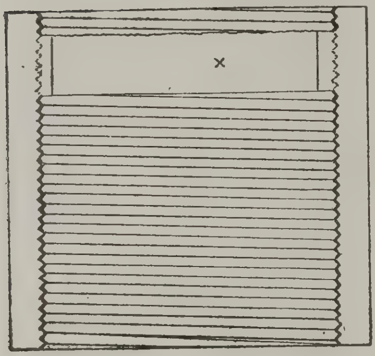


Fig. 26.

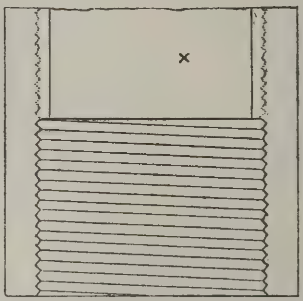


Fig. 27.

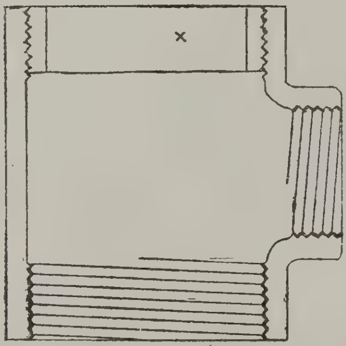


Fig. 28.

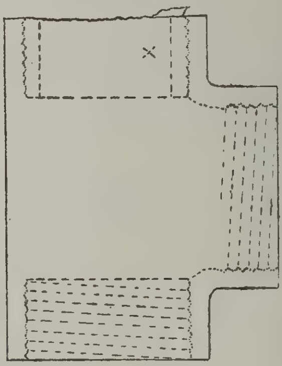


Fig. 25. 2″ Pipe.
Fig. 26. 1″½ Pipe.
Fig. 27. 1″½ „
Fig. 28. 1″ „

As will be seen from figs. 25 and 26, in each of the three cases of the simple joints, *E*, *C*, and *G*, with no transverse branching, the thin end of the tube fitting into the wrought iron coupling was broken at, or a slight distance within, the edge of the latter, due evidently to the reduction to 1½ mm. or so of the thickness of the tubing by the screw cutting. None of the wrought iron couplings were broken.

The six other screw joints for the connection of the 1″¼ to 2″ pipes were of cast iron and fitted also for a normal side insertion of 1″ wrought iron pipe.

Broken Cast-iron Gas-pipe Socket.

Fig. 29.

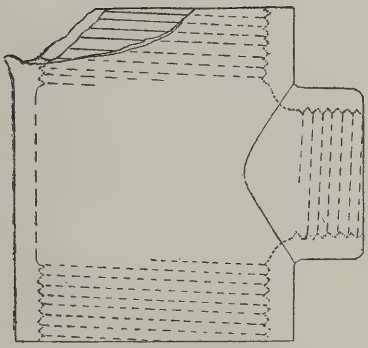


Fig. 30.

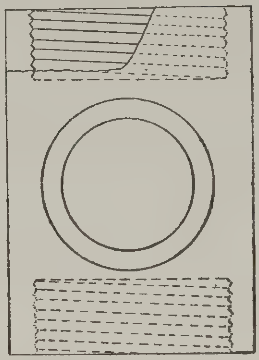


Fig. 31.

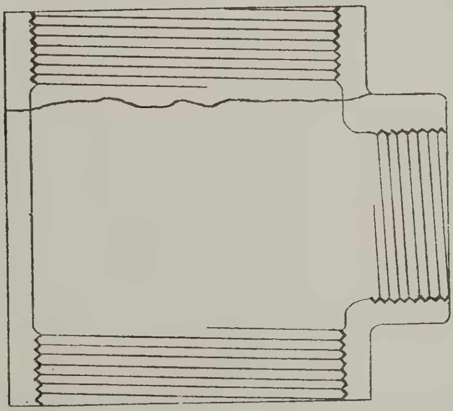


Fig. 29.	1″½	Pipe.
Fig. 30.	1″¼	„
Fig. 31.	2″	„

Four of these, *B*, *F*, *D*, and *I*, (figs. 29, 30, and 31) were broken transversally in a complete or partial manner at the junction with the latter. In case of the 2″ pipe joint, *B* (fig. 31), laid along the strand street, extending nearly north-south, namely, approximately normal to the direction of the maximum earthquake motion, the coupling was obviously broken by the strong transverse thrust exerted by the 1″ pipe branching from it eastwards or westwards. In the 1″ joint *H* (fig. 28), the coupling was not damaged, but one of the adjoining 1″ pipes had its screwed end torn off and partly crushed inside, showing clearly that the effect was due, not to a tension, but to a cross bending action. In the remaining 1″½ joint, the socket was not damaged, but the screw end of one of the pipes fitting into it was broken off apparently by tension.

Beside the damage done to the joints above mentioned, there was a case of fracture of a 2″ cast brass main cock on the Sengok-babadori (千石馬場通) at the east abutment of the Nishida-bridge (西田橋) in the western part of the city.

Again, at several places the $\frac{3}{4}$″ gas-metre pipes were torn off.

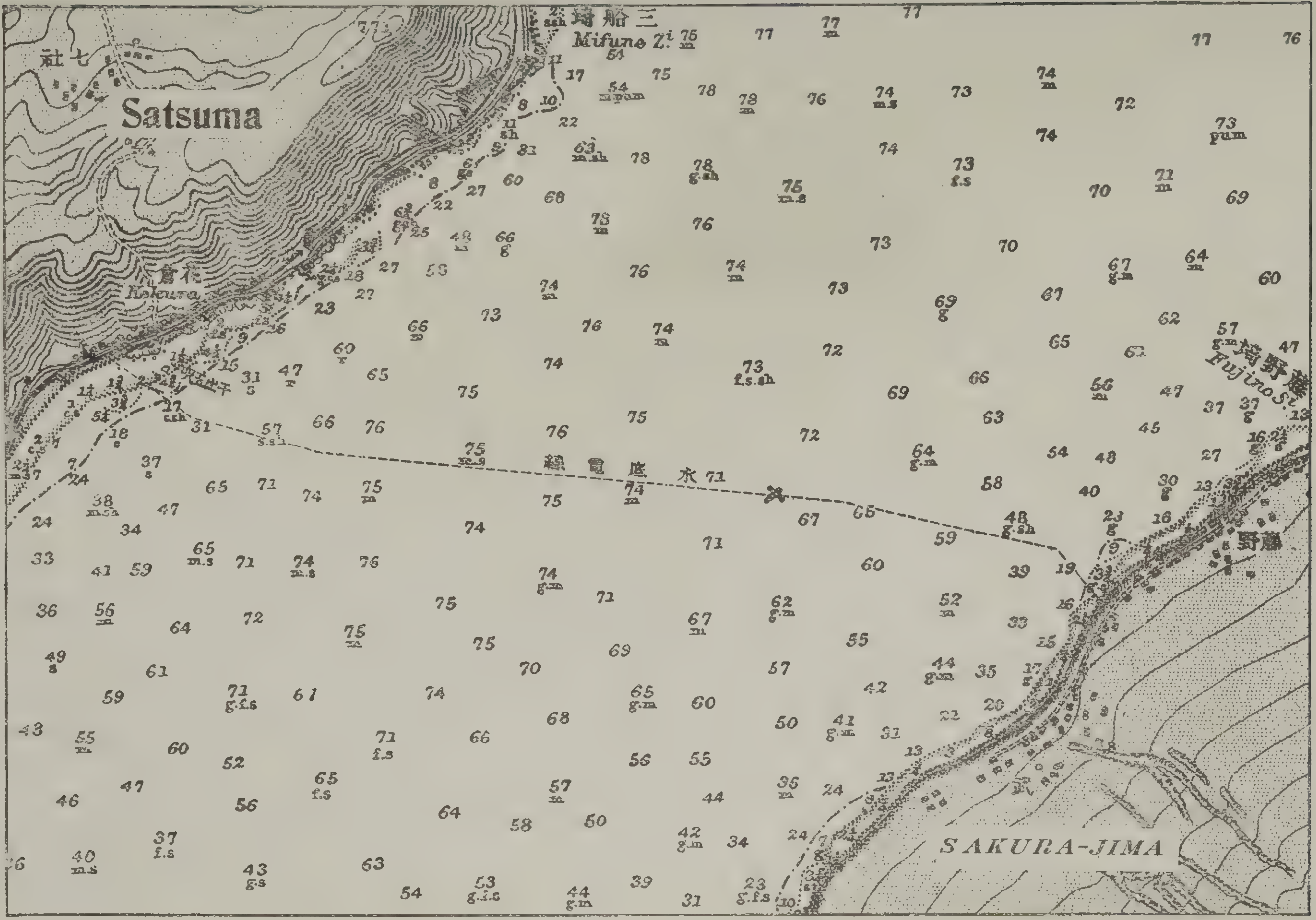
A partial gas circulation was restored 11 days after the commencement of the eruption, namely, on Jan. 23rd, the general gas light use throughout the city having been effected two days later on. During the subsequent days, till Feb. 21st, the leakage amounted to 45%. At the commencement of April next it was reduced to 25%, being still much greater than the value of 15% for the epoch previous to the occurrence of the earthquakes.

12. Damage to the Railways. The damage done to the railways was slight and restricted to the distance of 9 km. to the north, and $15\frac{1}{2}$ km. to

Table IV. Damage to the Railways.

Mileage. (from Moji.)	Damage to the Railway.
	Main Kyushu Line.
$233^m\ 21^c$	A stone block about 70 c. ft. in volume, thrown down from the right-hand side cliff, obstructed the road.
$233^m\ 37^c$	A stone block about 40 c. ft. in size fell on the road.
234^m	54 stone blocks varying in size from 2 to 100 c. ft. were precipitated on the road from the mountain slope on the righthand side about 200′ in height, bending one rail and breaking 8 sleepers.
$235^m\ 16^c - 21^c$	108 stone blocks of 2 to 200 c. ft. in size fell on the road from the mountain slope on the righthand side about 300′ in height, breaking 4 and bending 11 rails, breaking 6 fish-plate joints, and breaking 40 sleepers.
$235^m\ 30^c - 35^c$	About 20 stone blocks of 20 to 800 c. ft. in size fell on the road from the mountain slope on the righthand side about 150′ high, breaking 5 and bending 7 rails, and breaking 15 and bending 3 fish-plate joints.
$235^m\ 37^c$	A stone block about 200 c. ft. in size fell on the road from the right-hand side cliff, causing the bending of a rail.
$235^m\ 39^c$	2 stone blocks about 80 c. ft. in size fell on the road.
	Kagoshima-Sendai Line.
$3^m\ 0^c - 30^c$ (Between Take and Manju-ishi.)	The approaches to the bridge were depressed 4″ to 9″.
$3^m\ 70^c - 4^m$	The railway was slightly bent and the embankment was cracked 3″ wide and 3 chains long.
9 27 – 29 (Between Manju-ishi and Ijuin.)	A cutting slid down over an area of 58 sq. *tsubo.*

Fig. 32. Chart of the Kagoshima Channel. Depth in fathoms.



Dotted line shows the location of the Submarine Cable.
(×)……Point of Fracture.

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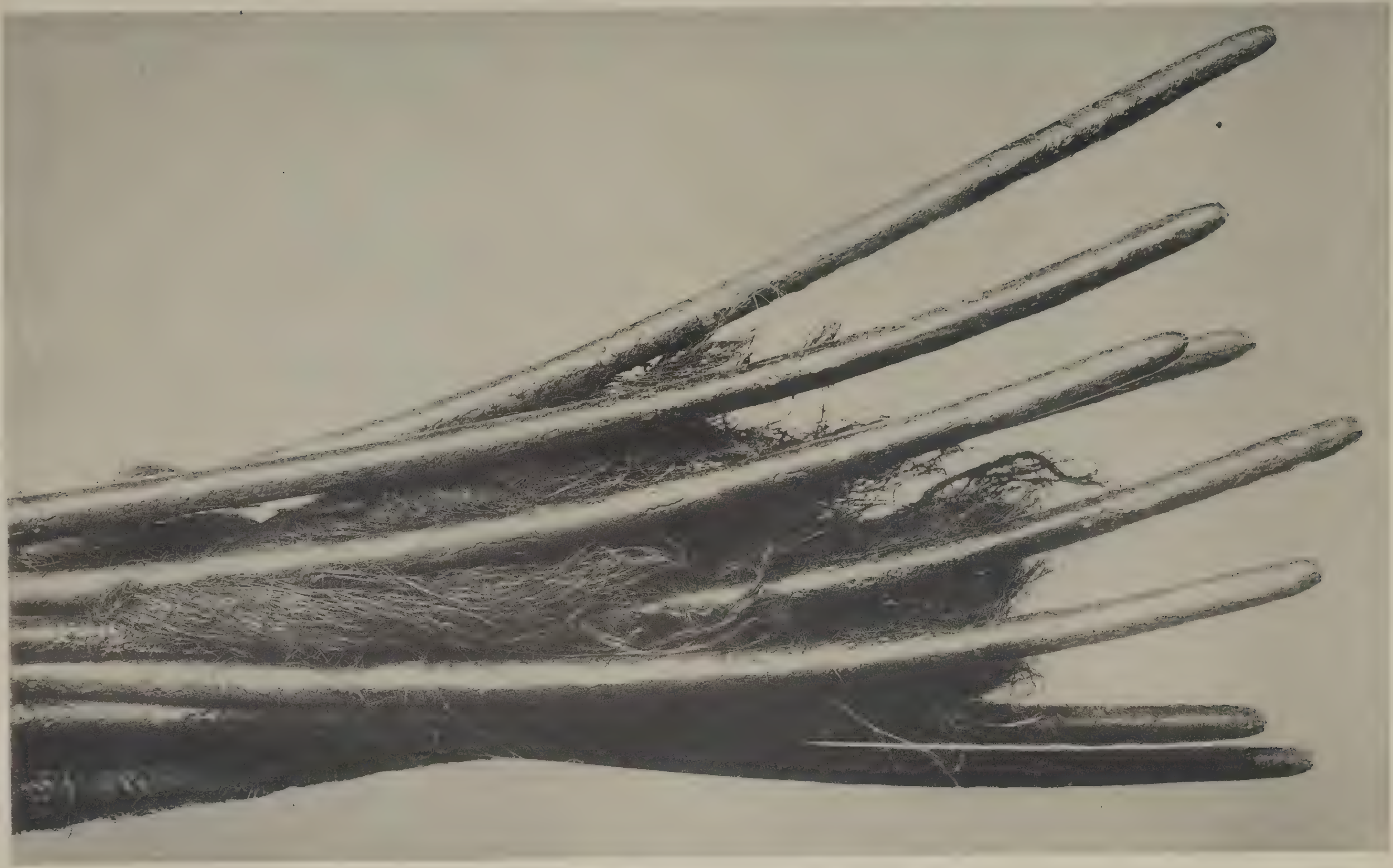

Fig. 33. An enlarged view of the Broken End of the 1″ Telegraphic Cable between Kagoshima and Sakura-jima.

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1″ Telegraphic Cable between Kagoshima and Sakura-jima.

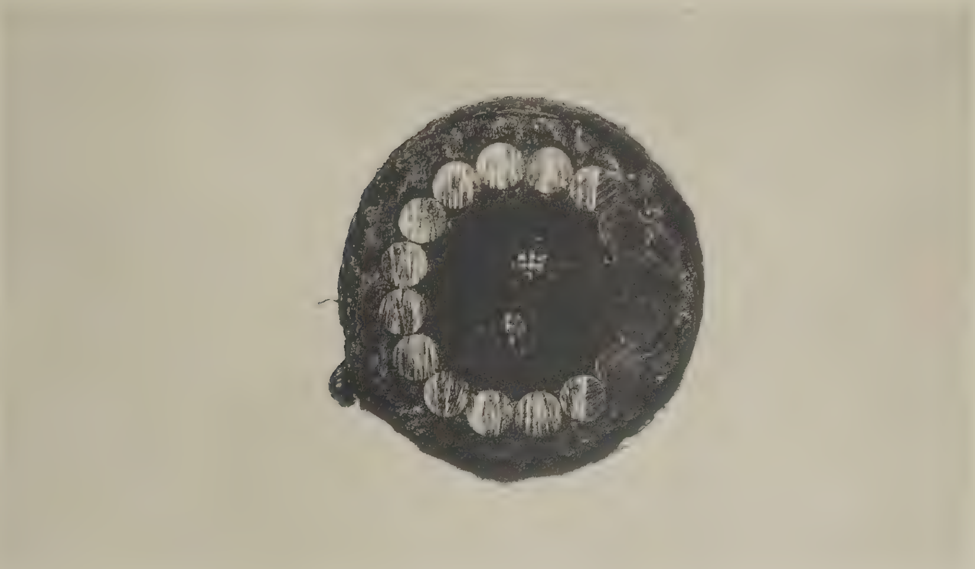

Fig. 34. Section.

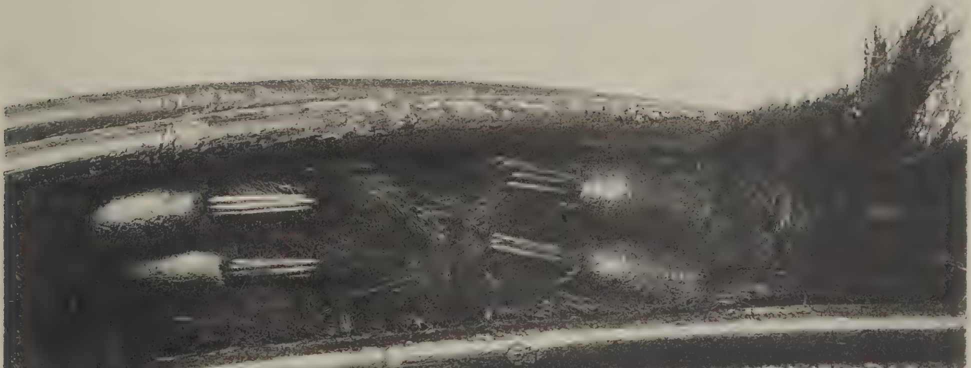

Fig. 35. An Inside Core-breaking.

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the west of Kagoshima. On the main Kyushu line laid to the north of the city along the steep western coast of the bay, there were at 7 different places, between the mileages of 233^{m} 21^{c} and 235^{m} 39^{c}, cases of precipitation of rock fragments from the cliff walls or the high mountain flanks on the righthand side of the road, resulting in a temporary obstruction or in the damage to the rails and sleepers. On the branch Kagoshima-Sendai line there were at three places, between the mileages of 3^{m} 0^{c} and 9^{m} 29^{c}, cases of a small land slip and of damage to the embankment.

CHAPTER II. SEISMIC DAMAGE TO SUBMARINE CABLE.

13. Submarine Cable Between Kagoshima and Sakura-jima. The damage done to the telegraph cable across the Kagoshima channel at the time of the recent Sakura-jima eruption furnishes a simple and interesting case of the action of submarine telluric convulsions. The broken cable has been examined very carefully by Dr. S. Inada,* of the Department of Communications, the result of his investigations being embodied in a short but valuable paper contributed to the Denki Gakkai Zasshi (Journal of the Electrotechnical Society), No. 344, (1917). The following description of the cable and of the damage done to it in §§ 14 and 15 and Tables V and VI are translations from Dr. Inada's paper.

The telegraph cable across the Kagoshima channel laid on Nov. 20, 1912, between Take, at the N.W. corner of Sakura-jima and Kekura 3 km. to the N. of Kagoshima, had the length of 1.812 sea miles, with the slack of about 7%, and the total weight of 12.6 tons, being composed of the double-core lines of the shore-end and intermediate types, as follows :—

Sakura-jima End.			Kagoshima End.
	(III)	(II)	(I)
Type.	Double-core Shore-end type.	Double-core Intermediate type.	Double-core Shore-end type.
Length.	0.405 n. mile.	1.012 nautial mile.	0.395 n. mile.
Armour Sheath.	10 = 300 mil	16 = 175 mil.	10 = 300 mil.
Weight of Core.	100 lbs. per n. mile.	100 lbs. per n. mile.	100 lbs. per n. mile.
Weight of Insulating Materials.	120 „	120 „	120 „ „
Weight per nautical mile.	8.7 tons.	5.6 tons.	8.7 „ „

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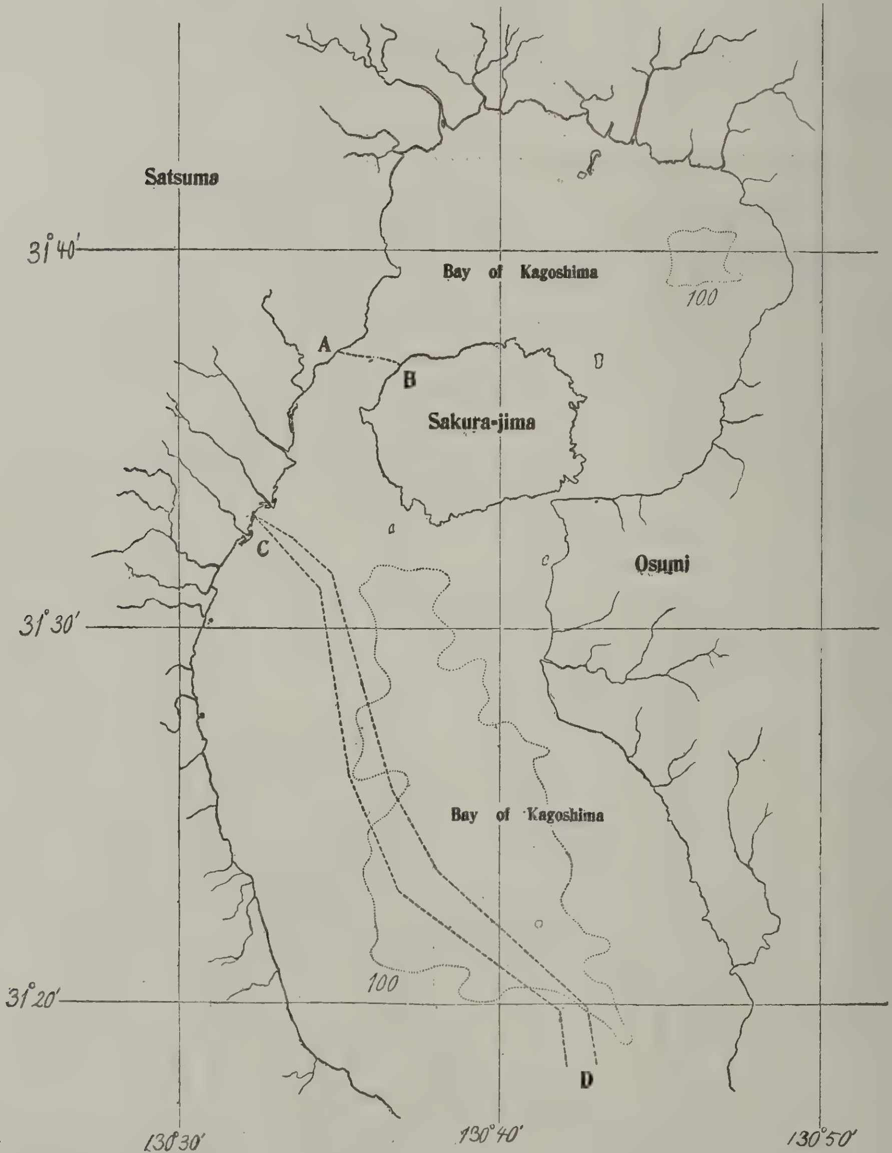
* Besides furnishing me with detailed accounts of his investigations, Dr. Inada has very kindly presented to the Seismological Institute the specimen pieces of the damaged cable.

Fig. 36. Chart ot the Kagoshima Bay, showing the Location of the Submarine Cables.

AB......Cable broken by the Earthquake of Jan. 12, 1914.
CD......Cables not damaged " "



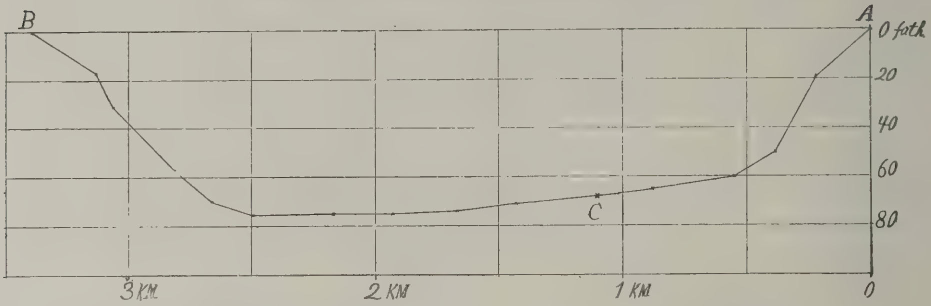
The double-core shore type line used in the Sakura-jima and Kagoshima side sections (I) and (II), 0.395 and 0.405 nautical miles in length respectively, had the diameter of 1.6 inches and had an armour sheath composed of ten 300-mil diameter iron wires, of tensile strength = 25 tons per sq. inch. Again, the double-core intermediate type line used in the middle section (II), 1.012 nautical miles in length, had the diameter of 1.3 inches, the armour sheath being made up of sixteen 175-mil diameter iron wires, of tensile strength = 30 tons per sq. in. The sectional area and the breaking tensile strength of the iron sheaths were as follows :—

Line.	Sectional Area.	Tensile Strength.
Double-core Shore-end Type.	0.706 sq. inch.	17.6 tons.
„ Intermediate Type.	0.387 „	11.6 „

As will be seen from figs. 32, 37, and 38 the cable crossed the deep northern portion of the Kagoshima channel, whose banks have steep declivity and whose bottom, generally muddy and favourable for the laying of cables, was 50 to 75 fathoms in depth.

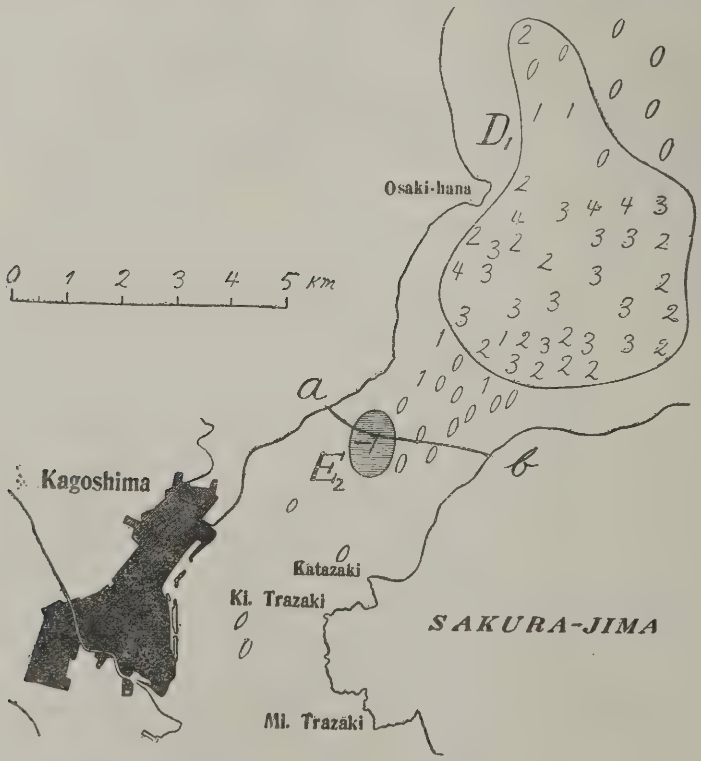
14. Damage to the Cable. On the day of the Sakura-jima eruption, Jan. 12th, 1914, the cable functioned without hinderance till about 2 P.M., when the telegraphic operation was suspended, the island being then nearly deserted and the Sakura-jima terminal post and the neighbouring houses burnt by the hot lava fragments. On trial the next morning the communication was found cut off. The interrupted cable was left in the damaged condition for nearly 3 years, till Dec. 1916, when the cable laying steamer Okinawa-Maru was dispatched to the scene of disturbance for examination. Although the pumice and ashes had been precipitated to a thickness of over 1 foot, the cable terminal, buried sufficiently deep in the ground, was found intact, thereby indicating the submarine location of the point of damage. The latter was ascertained to be at the distance of 0.577 sea-mile from the coast of Sakura-jima, where the intermediate type cable was torn apart obviously by a powerful tension, and the iron wires of the armour sheath were stretched some 3 mm. and then broken, there being no contorsion of the line and no scratching of the outside surface as would have been the case, had the damage been due to a cross breaking, for example, caused artificially by anchor casting. There was also no indication of the cable having been buried by the volcanic débries to any considerable extent, as it was pulled up without ex-

Fig. 37. Diagram showing the Water Depth (in fathoms) along the Submarine Cable between Kagoshima and Sakura-jima.



B……Kagoshima (W.) End.
A……Sakura-jima (E.) End.
C……Point of Cable Fracture.

Fig. 38. Chart of the S. W. Portion of the Inner Kagoshima Bay, showing Changes in the Depth before and after the Sakura-jima Eruption of 1914.



ab……Submarine Cable.
D_1……One of the portions of the bay where the bottom was depressed more than 1 fathom.
E_2……One of the elevated portions of the bay bottom.

The figures indicate the amount of change of the water depth, in fathoms, plus (+) when augmented, and minus (−) when lessened.

periencing much resistance (tension). It is to be remarked that the cable was broken, not at the steep banks of the Kagoshima strait, but at the flat bottom about one-third of the width from the coast of Sakura-jima.

The cable was repaired by substituting a new intermediate-type line for the length of 1,111 metres, between the two points P and Q, 530 and 1,567 metres distant from the Sakura-jima and the Kagoshima ends respectively. What was remarkable was the fact that, apart from the fracture at the point C (fig. 37) the old pulled-up portions of the cable, CQ and PC, were found somehow damaged and incapable of transmitting electic current. On stripping off the armour sheathing, the core lines and the serving were found cut off, at first the two together at short distances, then the serving only, at longer intervals with increase of the distance from the point of fracture. This internal damage was ascertained to extend from the latter for the distances of 58 and 167 metres toward the Sakura-jima and the Kagoshima sides respectively.

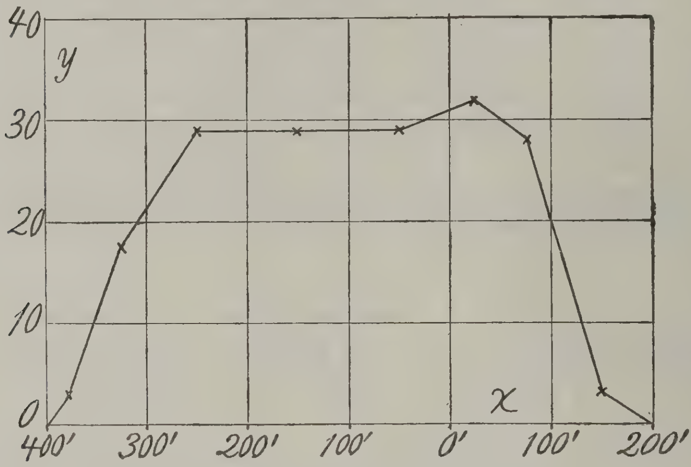
	Sakura-jima side.	Kagoshima side.
Core and Serving broken together.	20 places	26 places.
Serving only broken	46 ,,	168 ,,

The average interval between the successive core or serving breakage was, according to Tables V and VI, on the whole constant and equal to 1.7 feet for the distances of 102 and 319 feet from the point of cable fracture toward the Sakura-jima and the Kagoshima ends respectively, as follows :—

Direction.	Successive Length.		Mean Interval between successive points of breakage.		N=Number of breakage for the length of 50′
Westwards from the Point of Fracture C.	117′.9	Sum, 319′.3	1′.84	Average, 1′.7	27
	103.9		1.68		30
	97.5		1.58		32
	57.6		2.74		18
	18.0		18.0		28
Eastwards from the Point of Fracture C.	46.9	Sum, 101.8	1.56	Average, 1′.7	32
	54.9		1.77		28
	88.0		14.7		3.4

The frequency (=N), or the number of breakage for the length of each 50 feet, was thus approximately 30 for the distance of 420 feet about the point of fracture, the decrease being thereafter very quick. (See the illustration in fig. 39.).

Fig. 39. Diagram showing the Frequency of the Core and Serving Breakage of the Submarine Cable.



{x=Distance, in foot, from the point of Fracture.
{y=Number of Breakage for every 50-foot Length.

15. Effect of Electric Discharge. The cable was also affected electrically by the Sakura-jima eruption which was accompanied by marked display of lightnings from among the smokes; there being found a trace of a powerful electric discharge at the distance of 1,020 metres from the Sakura-jima end, where the serving in the cable was charred black to the size of a pea.

16. Cause of Cable Fracture. From § 14 it will be seen that the cable was torn apart as the result of a strong tension which existed locally for the extension of only 58+167=265 metres about the point of fracture, the breaking of the core lines and the serving at numerous places being evidently the antecedent effects produced by the application of the same force. The exact moment of the cable fracture can not be ascertained. But most naturally we are led to connect the effect in question with the destructive earthquake shock at 6½ P.M. on the 12th (January, 1914), which was followed about 1½ hours later on by small *tsunami* (tidal waves). The latter caused some damage in the hourbour of Kagoshima, but was insignificant along the other parts of the coast of the Kagoshima bay, being probably the result of the formation of vertical disturbances of the sea bottom in the immediate vicinity.

The fracture of the cable was probably not the direct effect of the earthquake shock itself. Thus, suppose a portion *ab* (fig. 40) of the cable to be more or less buried in the sandy or muddy material of the sea bottom, while the adjacent portion *bc* was suspended in the water. If the direction of the earthquake motion, of intensity $=a$ mm/sec.^{2} be parallel to the cable, the destructive force at *b* would be equal to

$$P=\frac{W}{g}\times a,$$

where W is the weight of the free portion *bc*, and *g* the acceleration due to the gravity. The cable, of the intermediate type, would be broken if P becomes equal to the tensile strength, namely, 11.6 tons. In that case we have

$$W=gP\times\frac{1}{a}=9800\times 11.6\times\frac{1}{a}.$$

If $a=2000$ mm./sec^2. and 3000 mm./sec.^{2}, W becomes respectively 58 and 34.8 tons. But, as the weight per mile of the intermediate-type cable was 5.6 tons, these values of W correspond to the length of 10 and 6 miles, being much greater than the whole length of the cable. In other words, the fracture in the manner here assumed would be impossible, although the direction of the strong earthquake motion was in reality approximately parallel to the extension of the cable.

On the other hand, the earthquake very likely produced, or was followed by the formation of, a vertical displacement, or a horizontal displacement, or displacements in the two directions combined, at the sea bottom. (1), As a simple case of a vertical displacement, let us suppose the sea bottom, *abc* (fig. 41), originally plane, was partly upheaved and partly depressed and converted into a curved form *a d b e c* (fig. 42). The cable, formerly in contact with the sea bottom, would be stretched into a sort of chord across the curve, *dc*, and might be broken by tension, if buried or otherwise fixed at the two ends *d* and *c*. (ii), with regards to the horizontal displacement, the portion of the sea bottom, *ac*, might have suffered an elongation, in which case the cable would naturally be broken by tension. That there took place some disturbances of the sea-bottom of the nature here supposed at the time of or soon after the severe earthquake is very probable, as the latter was followed by a *tsunami*. Further, the great Sakura-jima eruption (1914) was attended by a subsequent depression of the ground, which was specially marked in the Inner Kagoshima Bay. In fact the bottom of the latter was generally depressed from ½ to 4 fathoms, with the exception of the two isolated portions where the ground was elevated to the amount of 1 to 3 fathoms; the submarine cable under consideration having been laid just across one of these elevated areas, (fig. 38). Again, the different trigonometrical points in Sakura-jima and about the Kagoshima bay were more or less displaced horizontally; the change at the N. and N.W. parts of the island being much greater than along the coast of Kagoshima and amounting to 2.62 to 4.52 metres, directed toward the N.E. or the N.*) From these facts it may be concluded that the bottom of the northern part of the Kagoshima strait, across which the cable had been laid, was subject to pronounced vertical changes combined with the elongation movements in the horizontal direction.

Diagram illustrating the Tension Effect on the Submarine Cable (*ac*).

Fig. 40.

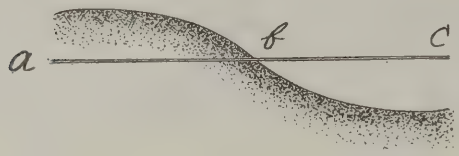


Fig. 41.

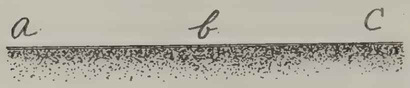
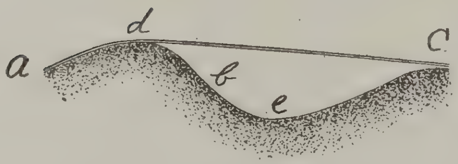


Fig. 42.



Now with regards to the action of a strong tension along a submarine telegraphic cable, the first effect will be to untwist slightly the outside iron wires, thereby pressing tightly the inside serving. The latter and the thin copper core wires, subject to stretching, willt hus be virtually clamped at several points along the length of the cable under tension and prevented from sliding within the armour sheath. As the result the serving and the core wires will be cut at numerous places one after the other with the increase of the tension, whose application may be supposed to be gradual. This process goes on till the iron sheath wires are finally torn apart. Such was probably what took place with the cable between Kagoshima and Sakura-jima under question. The average interval between the successive points of breakage of the serving and the core was 1.7 feet, being a little longer than the length of the armour sheath corresponding to one complete convolution of the constituent iron wires, which was equal to about 1.3 feet.

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*) See the Bulletin, Vol. VIII, Nos. 2 and 4.

From the existence of numerous breakage points in the core and the service it is to be inferred that the sea-bottom changes which exerted the tension along the cable was formed gradually. Had the application of the tension been instantaneous, the cable would have been broken at a single place, without damaging the material inside the armour at several points.

As will be seen from fig. 33, the iron wires of the sheath, each of diameter = 175 *mil*, were first drawn out a little with an appreciable reduction of the diameter and were then broken. From fig. 35, which illustrates the damage done to the core, it will be seen that the gum-covering was also drawn out and contracted before the breaking of the thin copper wires.

17. Cables between Kagoshima and Onejime. In May 1910 two telegraph cables were laid across the outer Kagoshima bay between the town of Taniyama 8 km. to the south of the city of Kagoshima and the town of Onejime on the coast of the province of Osumi. The submarine lines run in the direction of N. W.—S. E. Although they are at the nearest distance of only about 5 km. from the S. W. coast of Sakura-jima, they received no damage from the recent volcanic and seismic convulsions, due doubtless to the absence of the marked sea-bottom disturbances in the bay to the south of Sakura-jima.

18. A Case of Non-seismic Cable Fracture. The breaking at several points of the serving and the core is probably not limited to the case of the Sakura-jima earthquake under consideration, but may *always* take place when a submarine telegraphic cable is broken by tension. This was exemplified in the course of the repair work on the intermediate type cable in the Tsugar strait (between Aomori and Hakodate) in 1910, which had been laid in 1890, and partly much buried.* While the cable, whose sheathing was composed of 12 iron wires of 0.175 inch diameter, was being hauled up, it was broken by a tension of 9 tons near the wheel about 15 feet distant from the paying-out drum. The portion, which fell into the sea, had to be abandoned and could not be examined. But, for about 40 feet of the paying-out drum end of the broken cable, the serving and the core were found cut to pieces, varying from 0.5 to 4 feet in length.

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*) The details of the repair work were kindly communicated to me by Dr. Inada in a letter under the date of July 9, 1920.

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Table V. Damage to the Core and Serving of the Kagoshima and Sakura-jima Cable on the Adjacent Sakura-jima Side of the Point of Fracture.

(* 1 shaku = 0.994 foot.)

Interval.*	Damage.	Interval.	Damage.	Interval.	Damage.
shaku		shaku		shaku	
1.1	Core broken.	1.3	Jute broken, Core intact.	1.0	Jute broken, Core intact.
1.5	Jute broken, Core intact.	1.7	Core wire broken.	1.5	"
1.3	Core broken.	1.0	Jute broken, Core intact.	1.6	"
2.0	"	1.3	Core wires broken.	1.0	"
1.1	"	1.4	Jute broken, Core intact.	2.9	"
1.6	"	1.4	"	0.6	"
1.1	"	2.1	"	2.0	"
2.3	"	1.6	Core wires broken.	1.1	"
1.5	"	1.8	Jute broken, Core intact.	4.0	"
1.3	"	1.2	"	0.8	"
1.8	"	3.7	Core wires broken.	1.2	"
4.5	Jute broken, Core intact.	3.0	Jute broken, Core intact.	1.2	"
2.0	"	1.1	"	4.8	"
1.6	Core broken.	1.6	"	2.0	"
1.2	Jute broken, Core intact.	1.6	"	16.0	"
1.0	Core wires broken.	1.2	"	18.0	"
1.9	"	0.9	"	6.0	"
1.5	"	1.4	"	22.0	"
1.8	"	1.2	"	2.0	"
1.7	Jute broken, Core intact.	0.9	"	24.0	"
1.2	"	2.0	"	(Thereafter no more damage.)	
0.8	Core wires broken.	2.4	"		
0.9	Jute broken, Core intact.	2.9	"		

Table VI. Damage to the Core and Serving of the Kagoshima and Sakura-jima Cable on the Adjacent Kagoshima Side of the Point of Fracture.

Interval.	Damage.	Interval.	Damage.	Interval.	Damage.
shaku 1.3	Core and Jute broken.	shaku 1.2	Core contracted.	shaku 2.1	Jute broken, Core intact.
1.9	„	1.9	Jute broken, Core intact.	1.15	„
1.7	„	1.7	„	1.5	„
1.7	„	1.2	„	2.4	„
2.2	„	1.9	„	1.7	„
2.2	„	2.3	„	2.6	„
1.4	„	3.2	„	2.4	„
2.4	„	1.0	„	1.0	„
1.0	„	1.6	„	1.2	„
2.0	„	2.0	„	1.5	„
1.0	„	1.6	„	1.1	„
1.6	„	1.7	„	1.7	„
1.6	„	2.7	„	1.9	„
7.7	(Not examined.)	1.7	„	1.3	„
		2.1	„	2.3	„
1.6	Core contracted.	2.7	„	0.6	„
2.8	Core and Jute broken.	1.7	„	1.1	„
2.7	„	2.2	„	1.5	„
4.1	„	1.6	„	1.2	„
1.7	„	2.3	„	1.6	„
2.0	„	1.7	„	2.2	„
1.3	„	1.3	„	1.5	„
1.1	„	1.7	„	1.7	„
1.5	„	2.1	„	2.4	„
1.5	„	1.7	„	1.8	„
1.5	„	1.6	„	0.8	„
1.7	Jute broken.	2.1	„	2.3	Jute and Core broken.
2.4	Core contracted.	1.5	„	1.7	Jute broken, Core intact.
1.8	„	1.5	„	2.0	„
3.0	„	2.4	„	1.3	„
1.7	„	2.6	„	2.6	„
1.1	„	1.5	„	1.6	„
1.4	Core and Jute broken.	2.3	„	1.2	„
1.7	„	1.4	„	1.2	„
1.1	„	2.1	„	1.5	„

Table VI. Damage to the Core and Serving of the Kagoshima and Sakura-jima Cable on the Adjacent Kagoshima Side of the Point of Fracture.

(*Continued.*)

In-terval.	Damage.	In-terval	Damage.	In-terval.	Damage.
shaku		shaku		shaku	
1.4	Jute broken, Core intact.	1.9	Jute broken, Core intact.	2.1	Jute broken, Core intact.
2.0	”	2.2	”	1.1	”
1.9	”	2.0	”	1.2	”
1.5	”	0.8	”	1.1	”
2.1	”	1.4	”	1.7	”
1.4	”	2.0	Jute and Core broken.	2.0	”
1.7	”	2.3	Jute broken, Core intact.	1.7	”
2.0	”	2.1	”	2.2	”
1.3	”	1.1	”	2.1	”
2.4	”	1.1	”	1.9	”
1.8	”	1.2	G.P. turned yellow, Core wire broken.	0.9	”
1.2	”	2.4	G.P. charred black, Core broken.	4.0	”
1.1	”	1.2	Jute broken, Core intact.	1.4	”
1.7	”	1.2	”	2.0	”
2.2	G. P. cracked.	1.7	”	2.0	”
1.2	”	1.3	”	2.4	”
1.3	”	1.7	”	4.0	”
1.7	Jute broken, Core intact.	1.3	”	1.5	”
1.1	Jute and Core broken.	1.4	”	1.8	”
1.6	Jute broken, core intact.	1.6	”	2.5	”
1.4	”	1.4	”	2.0	”
1.8	”	1.3	”	1.3	”
1.9	”	1.2	”	1.1	”
1.8	”	1.5	”	2.9	”
1.3	Jute and Core broken.	1.6	”	2.6	”
2.5	Jute broken, Core intact.	1.4	”	2.3	”
1.2	”	1.3	”	4.2	”
1.4	”	1.2	”	3.2	”
1.9	”	1.5	”	2.5	”
2.6	”	1.6	”	2.3	”
1.6	”	1.4	”	5.4	”
1.5	”	0.8	”	6.0	”
1.1	”	0.9	”	18.0	”
1.8	”	1.3	”		
2.1	”	1.7	”	(Hereafter not examined.)	

CHAPTER III. SUPPLEMENTARY NOTES ON THE SAKURA-JIMA ERUPTION OF 1914.

19. Median Furrow. (Supplement to §§ 52 to 54, No. 3, of this Volume.) The formation of the *median furrow* (figs. 44 and 46) along the middle axis of the course of the *2nd stage* lava outflow AB, is due partly to the flowing down in lateral direction and partly to the contraction of the surface crust portion in the same direction (fig. 43). The result is the formation of a curved V-shaped canal *C′* along the median line *C* (fig. 44). The existence of the median furrow may be taken as being limited to lava streams flowing on a free unbounded area. In case of the confinement, or the flow, within a valley space *ab*, the cracks *C*, formed in consequence of the contraction, are necessarily narrow (fig. 45). Figs. 47 and 48 give the general and detail views of the median furrows of the lava streams at Yunohama (湯之濱) near the buried village of Arimra. In the case of fig. 48, the mouth breadth of the canal was 46 feet, and the vertical depth about 33 feet. (See fig. 46.)

Diagrams illustrating the Formation of the Median Furrow.
ACB ; A′C′B′...Cross section of a lava stream.

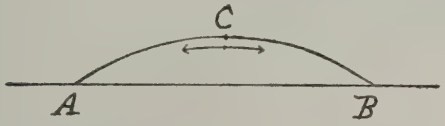

Fig. 43.

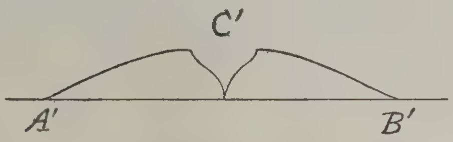

Fig. 44.

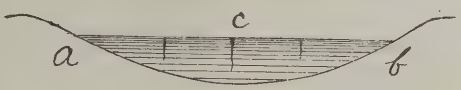

Fig. 45.

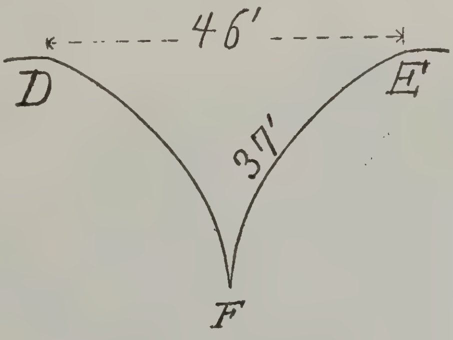

Fig. 46. Section of a Median Furrow.

20. Lava Islets. The new lava islets described in No. 3 of this Volume, are, in form, much similar to, but different in the formation process from, the median furrow. These islets have also invariably each a "cleavage canal," or a curved V-shaped axial depression, sometimes intersected by secondary transverse cracks ; the result being in many cases the formation of a miniature lake or pond occupying the central area. An islet of this type, with one of its ends partly covered by the lava stream of a later date, is found at the coast near the side of the buried village of Arimra, and has been named Arimra-Kojima (有村小嶋). (See the photograph, fig. 53.) The maximum width is 50 feet and the length about 450 feet. Figs. 49 to 54 illustrate the other lava islets formed off the new coast at the S. E. and the N. E. parts of the Sakura-jima, already described or referred to in p. p. 261—266.

Some of the differences between the *cleavage canal* and the *median furrow* are the following: the former is of sub-acqueous formation and more nearly horizontal, is composed of homogeneous massive material, is uniform in density, and is devoid of the reddish oxidation, characterizing the sub-aerial formation of the latter.

21. Nabe-yama Crack Ridge. Fig. 55 gives a general view from the west of the "canal", or eruption crack, formed across the Nabe-yama,* and figs. 56 and 57 enlarged views of the top ridge nearly in the E.-W. direction which is ashy and covered with lava blocks of various size and beyond which is laid the deep eastern branch of the crack. The length of the top ridge is 197 feet, and the height of the lava layer forming cliffs or "gate walls" on both sides of the canal is 50 feet (=15 metres). The north "gate wall" is dark red in colour, being much oxidized as the lava cascade which flowed along the N. W. flank of Nabe-yama. The south "gate wall" presented an apparently smooth surface, thin violet in colour, exhibiting no reddish oxidation effect; probably in consequence of the breaking off of the front surface of the lava layer. When seen on Oct. 13, 1916, the north "gate wall" was not fuming, but the roof area of the south "gate wall" was whitened with sublimates and was fuming considerably.

22. Ash and Lave Accumulation around the Craterlets. The inner exposed side of the peripheral wall of the craterlet No. 1 on the western slope of the Minami-dake shows very clearly the stratification of ashes, pumice and the solid lava layer. The rim of the craterlet, formed at the depressed portion lying to the north of a ridge connecting the parasitic cone of Hikinohira with the main central peaks of the island, is highest on the southern side, the sectional formation being as is indicated in fig. 58. The surface portion, 4.65 metres in thickness, is composed of several layers of ashes, pumice, and broken lava fragments, and represents the accumulation of the volcanic ejection during the 9 days following the active lava outflow stage, and ending with Jan. 22nd, when the craterlet in question became practically extinct. The underlying

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*) A good general view of the same crack taken from the east is given n Pl. LVIII of this Volume.

Median Furrow of the 2nd-Stage Lava Flow.

(F. Omori, phot.)

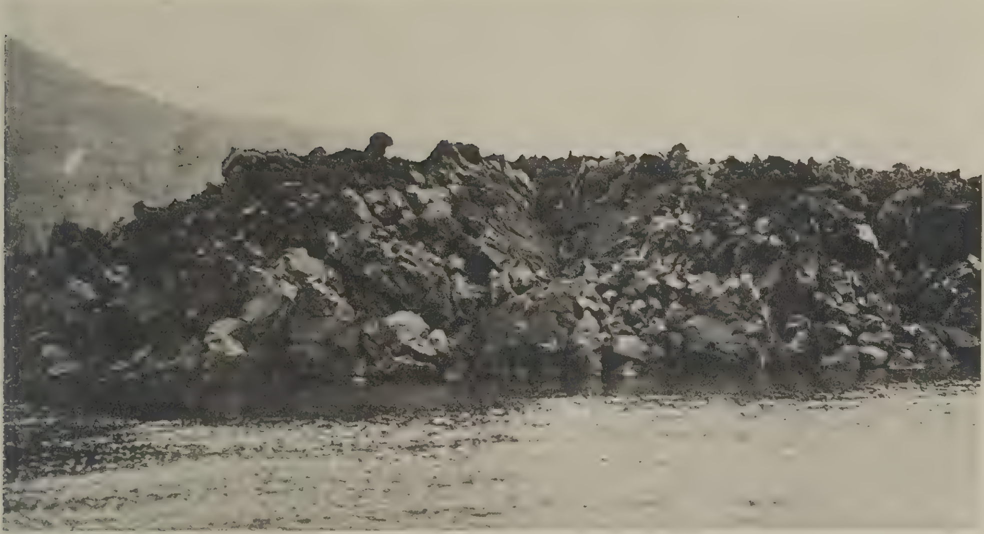

Fig. 47. A Lava Stream End, showing the Median Furrow. (Oct. 1916.)

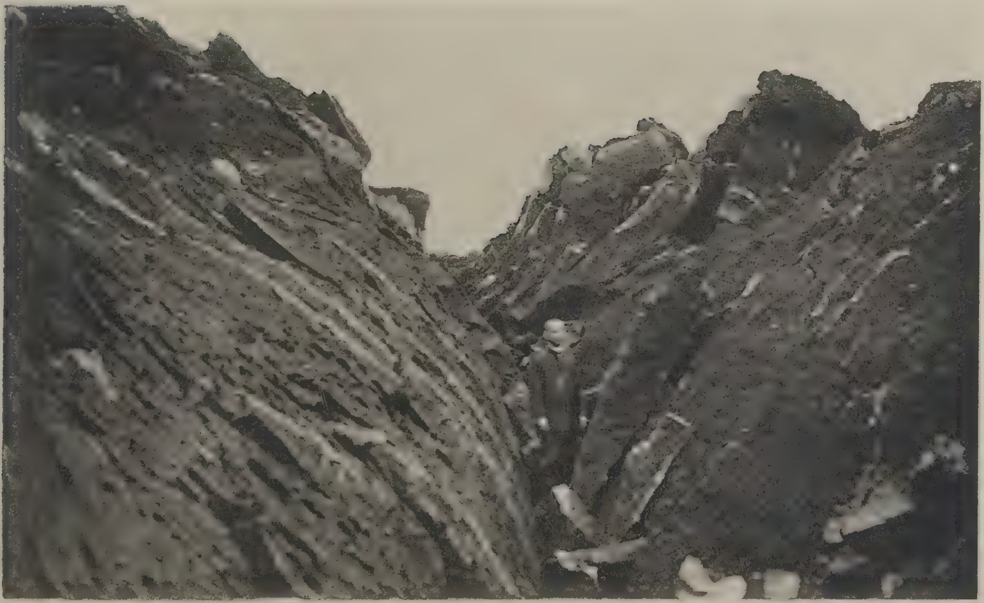

Fig. 48. An enlarged view of the V-shaped Median Furrow near the End of the Arimra-saki Lava Stream. (Oct. 1916.)

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The New Ushine-Oshima Lava Islets, formed off the N.E. Coast of Sakura-jima.

(F. Omori, phot.)

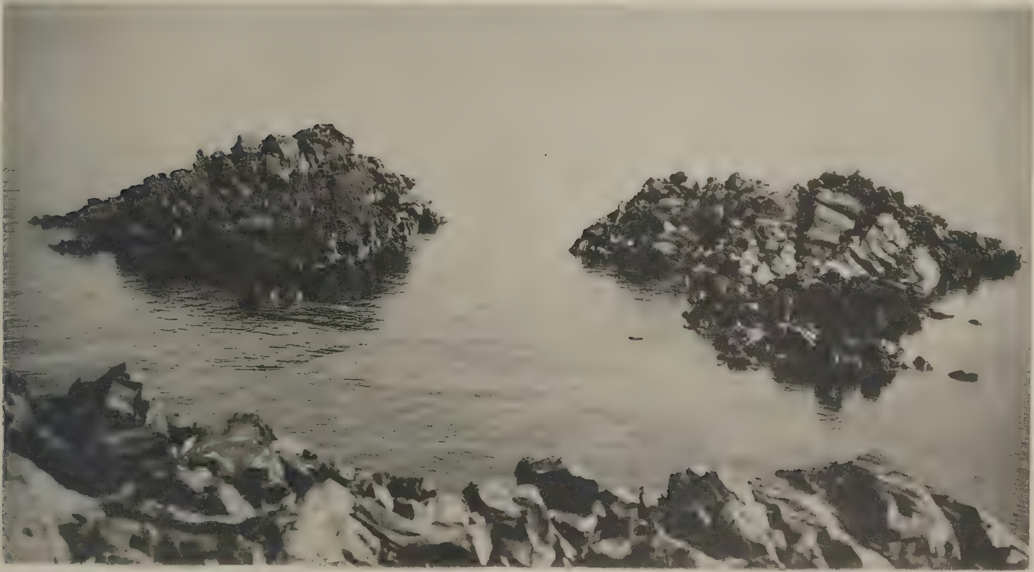

Fig. 49. View of the Two Small Islets and the Central Canal. (Oct. 1916.)

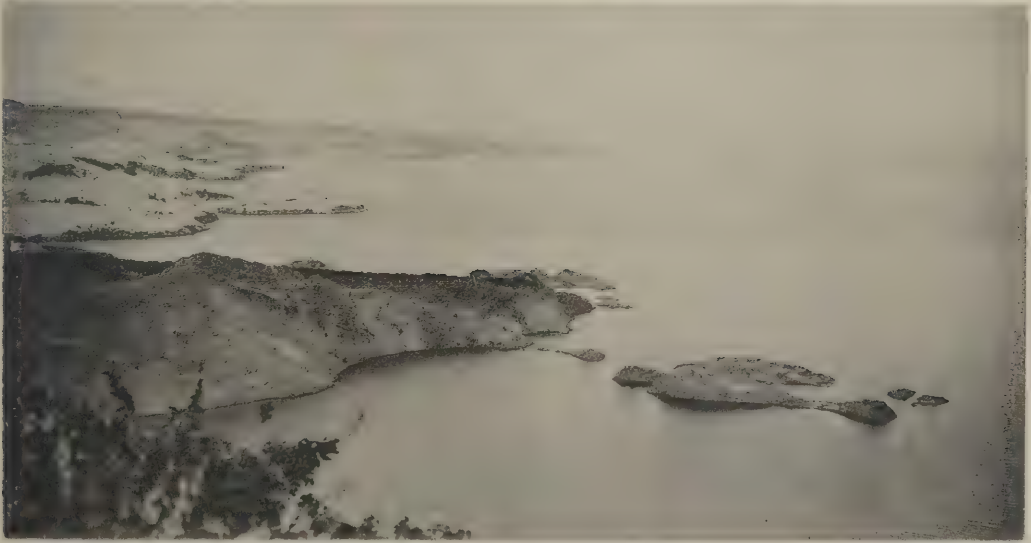

Fig. 50. General view of the group, taken from the top of Sakkabira. (Oct. 1916.)

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New Lava Islets on the S. E. Coast of Sakura-jima.

(F. Omori, phot.)

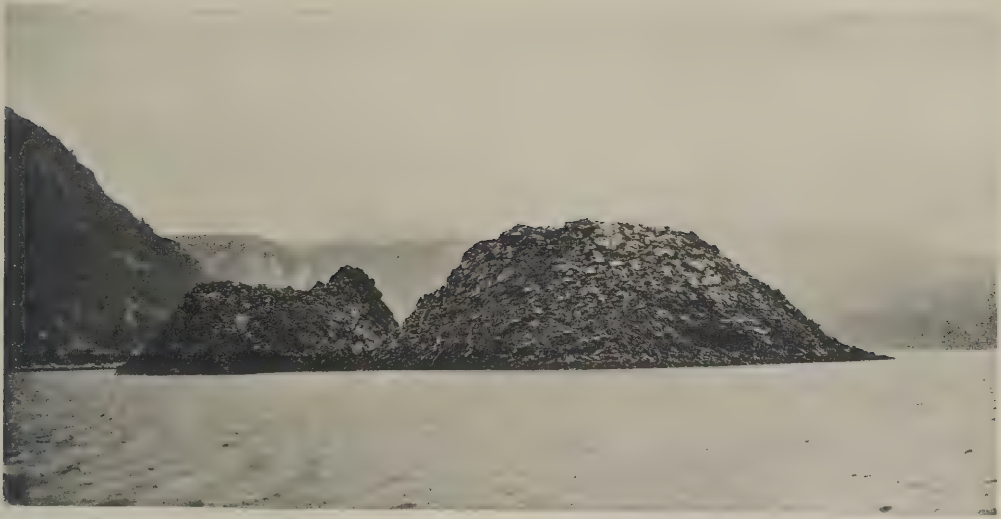

Fig. 51. Arimra-jima, showing the V-shaped Central canal. (May 1918.)

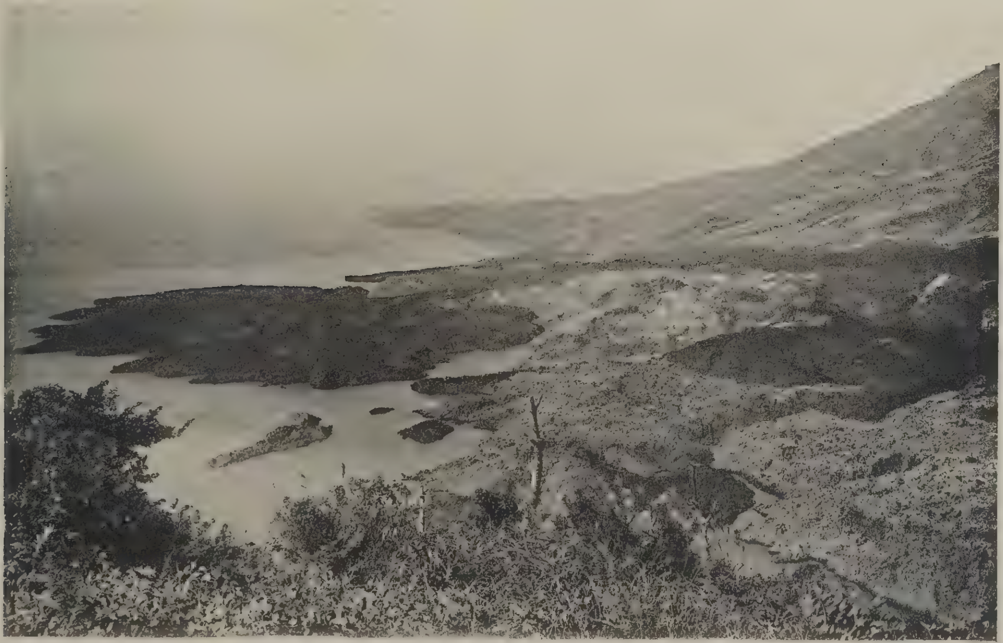

Fig. 52. The 2nd-Stage Lava Outflow and the Group of the New Lava Islats. Arimra-jima at the lefthand side. (Oct. 1916.)

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Pond filling the Central Canal of Lava Islet. (F. Omori, phot.)

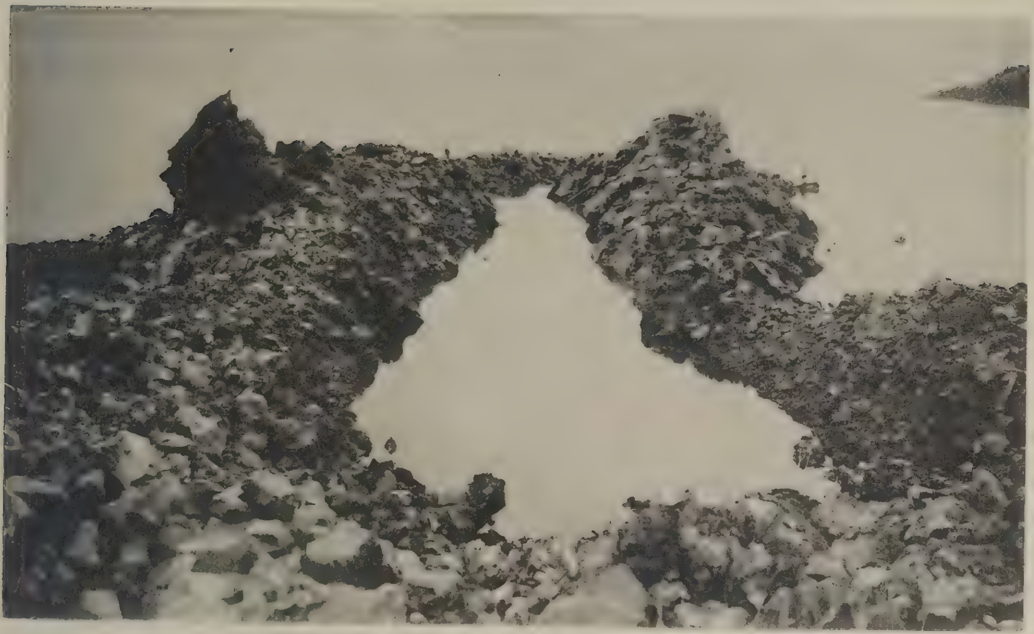

Fig. 53. An Islet adjoining the Coast of Arimra. (May 1918.)

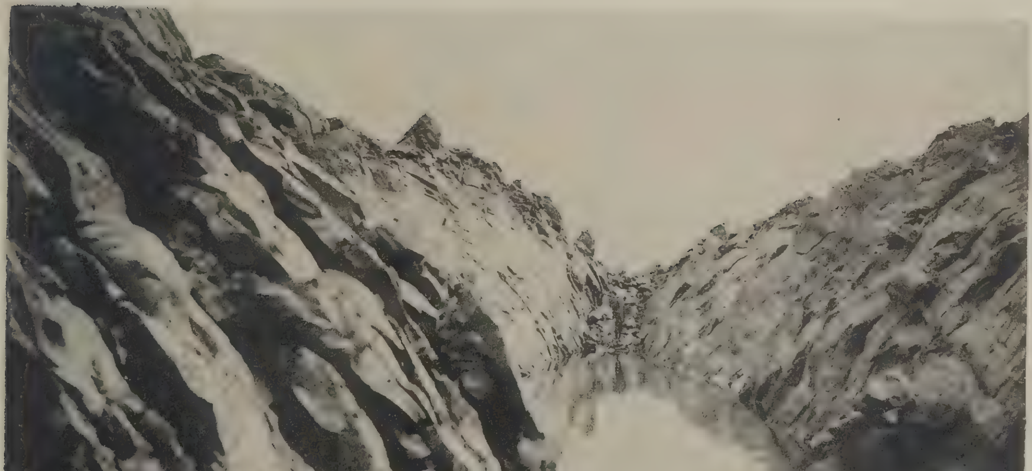

Fig. 54. Arimra-jima. (Oct. 1916.)

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Sakura-jima Eruption of 1914.

Nabe-yama Eruption Crack Line. (F. Omori, phot.)

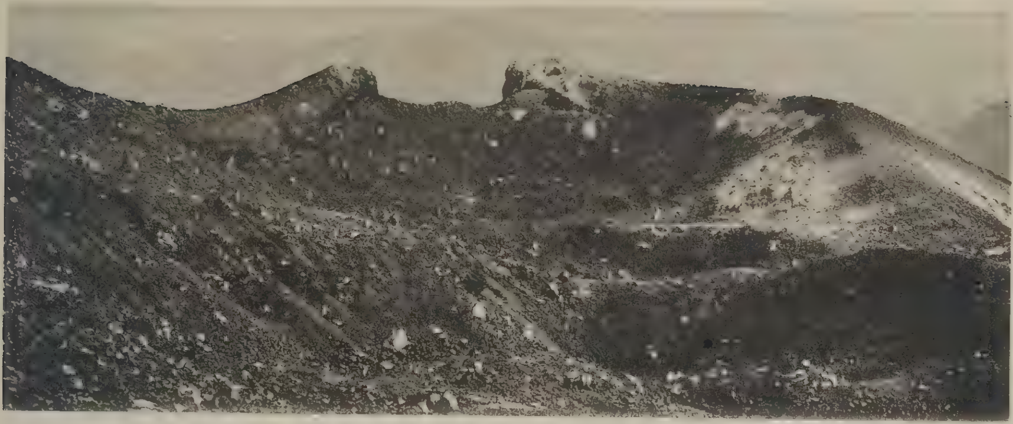

Fig. 55. General View of the Nabe-yama Crack from West. (Oct. 1916.)

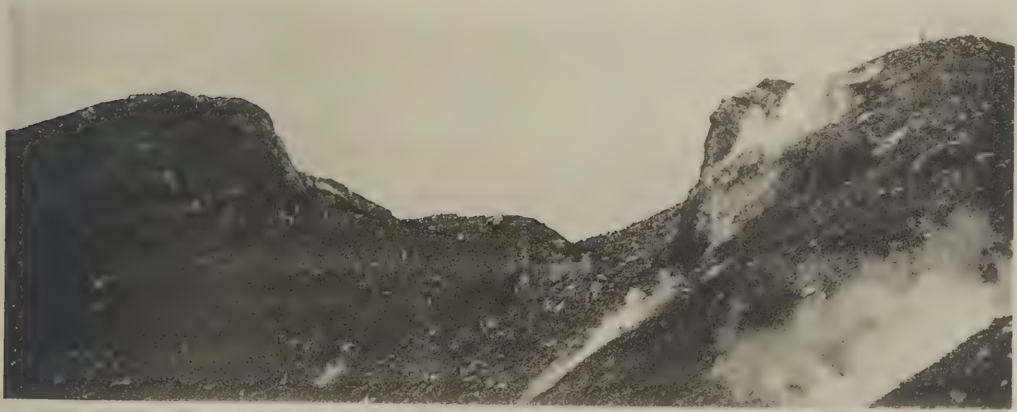

Fig. 56. The Top Transverse Ridge of the Crack. (Oct. 1916.)

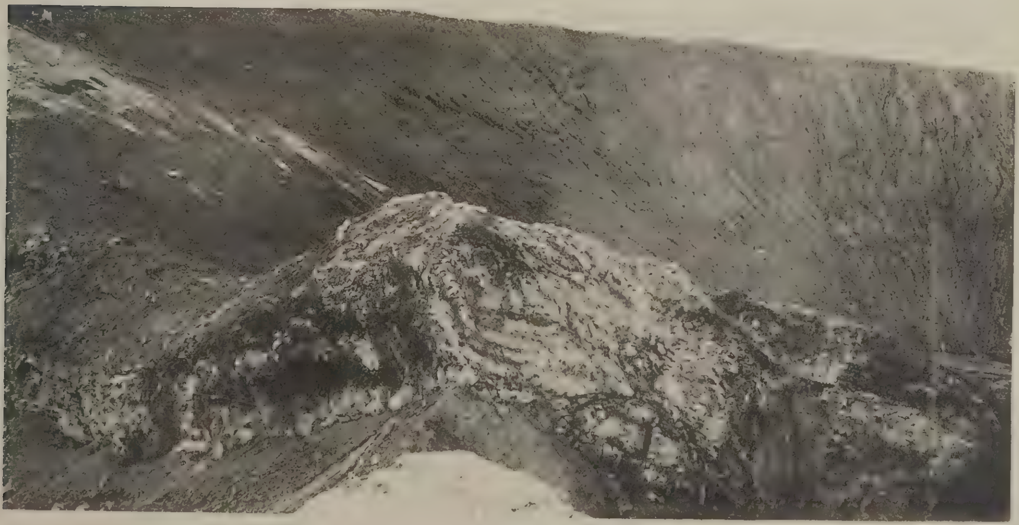

Fig. 57 The Cliff Edge of the Lava Layer on the S. Side. (Oct. 1916.)

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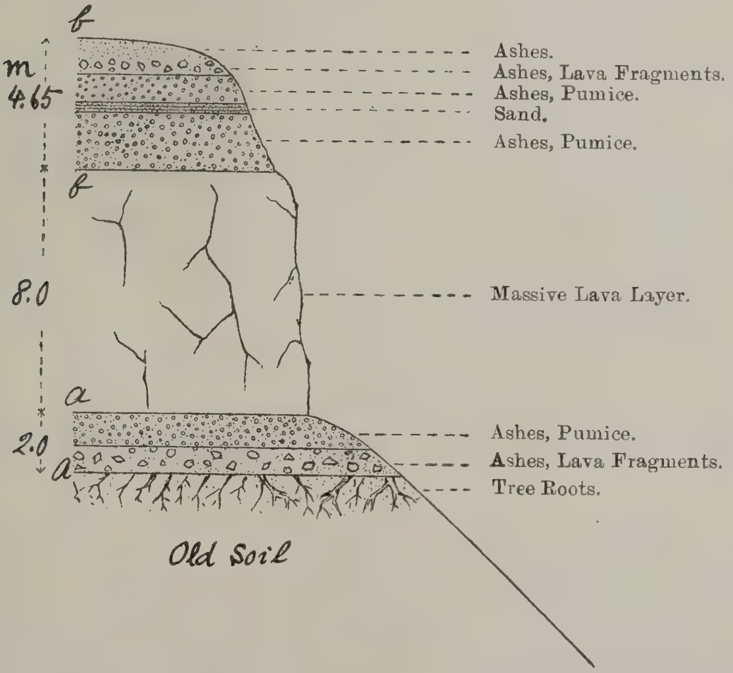
layer of massive rock is 8.35 metres in thickness and indicates the result of the lave overflow from the craterlet on the night of Jan. 13th (1914). Beneath this there are for the thickness of 2.0 metres two layers of loose formation, which represent the explosive products given out prior to the lava outflow; the upper being a mixture of ashes and pumice, and the lower containing angular lava pieces. So much, altogether 13.0 m. in depth, is the result of the eruption, the old natural black soil beneath containing many new dead tree roots which were not charred. (See fig. 59.) These roots belonged to trees smashed by the volcanic ejection or broken off by the volcanic winds. Some were the roots of wild roses, 2 cm. thick, or of the Japanese pines, 7 cm. thick. On the west side of the craterlet, the original soil is shown to the thickness of 2 metres at the foot of the wall formed by the new solid lava layer, which rests on the layers of pumice and rock fragments also about 2 m. thick. The thickness of the massive lava layer reaches the maximum amount of 20 metres toward the north where the craterlet rim is lowest. At the s.w. corner of the wall, the lava thickness is 11.3 metres. The actual

Fig. 58. Section of the S. Wall of the W. Craterlet No. 1.
Showing the Accumulation of the various Volcanic Materials.



then, by a slow recovery, or upheaval, whose amount was maximum and =0.168 m. at the coast of Osaki-hama about 10 km. to the north of Kagoshima, but only about 0.0045 m. at Ogawa-machi, the strand street of the latter city. Thus it is to be assumed that the sea-level height at the harbour of Kagoshima is since 1916 subject to no marked disturbance. The present mean sea-level at the latter place is about 1.82 *shaku* = 55 cm. higher than in 1903–1905. This agrees fairly well with the result of the leveling surveys, as the bench-

Table VIII. Yearly Highest and Mean Sea-level Heights at Kagoshima Harbour, Compared with the Yearly Mean Sea-level at Hososhima, 1914–1921.

Year.	Kagoshima Harbour.				Hososhima.*	
	Mean Highest Sea-level.	Mean Annual Sea-level.	Reduced to 1915.		Mean Annual Sea-level	*Do.* (Height referred to 1915.)
			Mean Highest Sea-level.	Mean Annual Sea-level.		
Before the Sakura-jima Eruption of 1914.						
	shaku	shaku	m.	m.	m.	m.
1903–1905	10.51	5.51	−0.494	−0.552	2.541	+0.013
After the Sakura-jima Eruption of 1914.						
	shaku	shaku	m.	m.	m.	m.
1914	12.06	——	−0.024	——	2.584	−0.030
1915	12.14	7.33	0.000	0.000	2.554	0.000
1916	12.07	7.19	−0.021	−0.043	2.550	+0.004
1917	11.90	6.93	−0.073	−0.121	2.650	−0.096
1918	11.99	7.02	−0.046	−0.094	2.658	−0.104
1919	12.21	7.13	+0.021	−0.061	2.601	−0.047
1920	11.85	6.87	−0.088	−0.139	2.627	−0.073
1921	11.86	6.97	−0.085	−0.109	2.634	−0.080
1922						

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* For the Kagoshima harbour, the sea-level *height* is expressed in *shaku* (=0.994 English foot). For the Hososhima station, the sea-level is indicated in the distance below a fixed point in the tide gauge room, so that a greater figure corresponds to a deeper or lower level of the sea-surface.

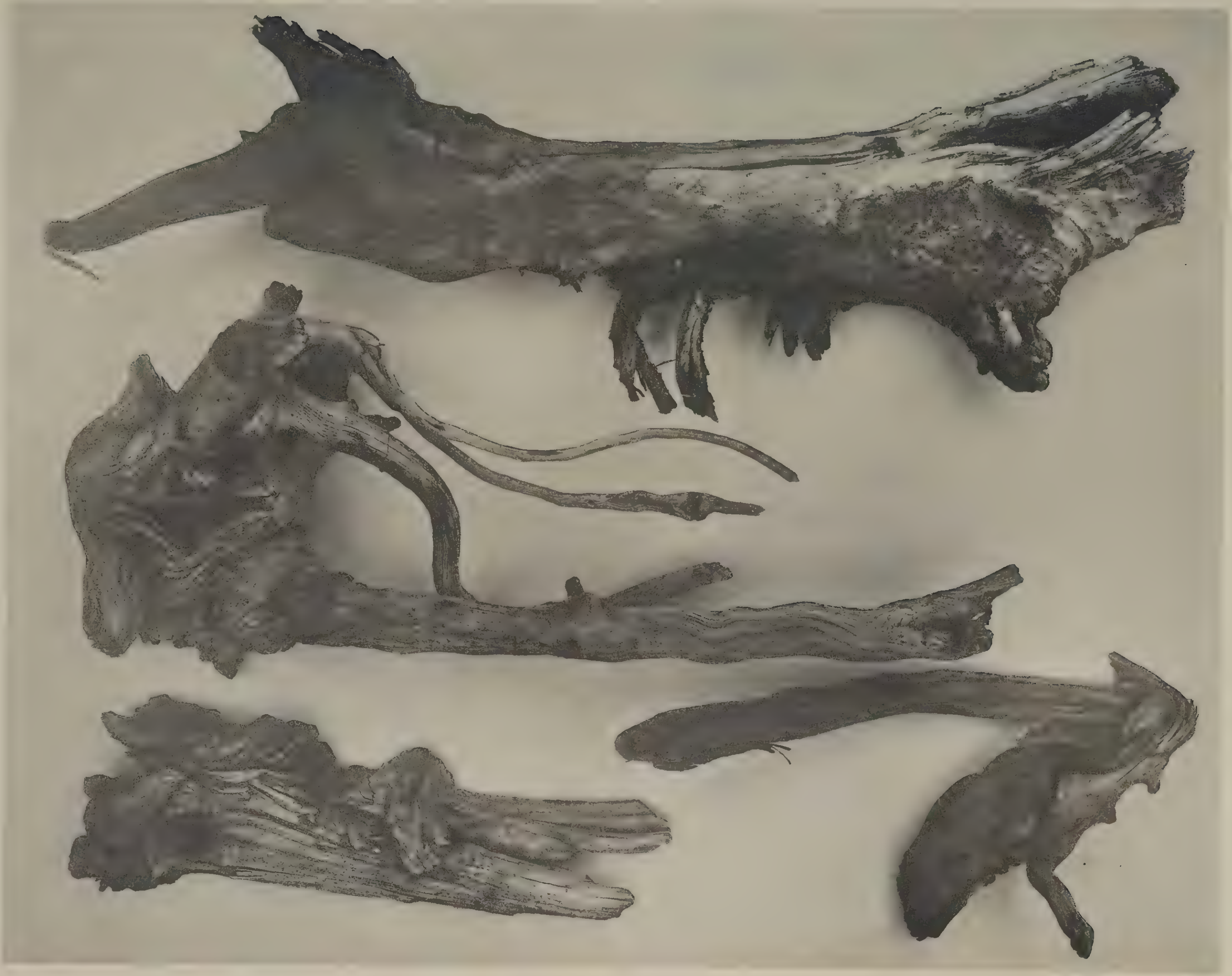

Fig. 59. Uncharred Tree Roots buried under the Ashes, Pumice and Lava Layers. (Natural Size.)

Sakura-jima Eruption of 1914. (F. Omori, phot.)

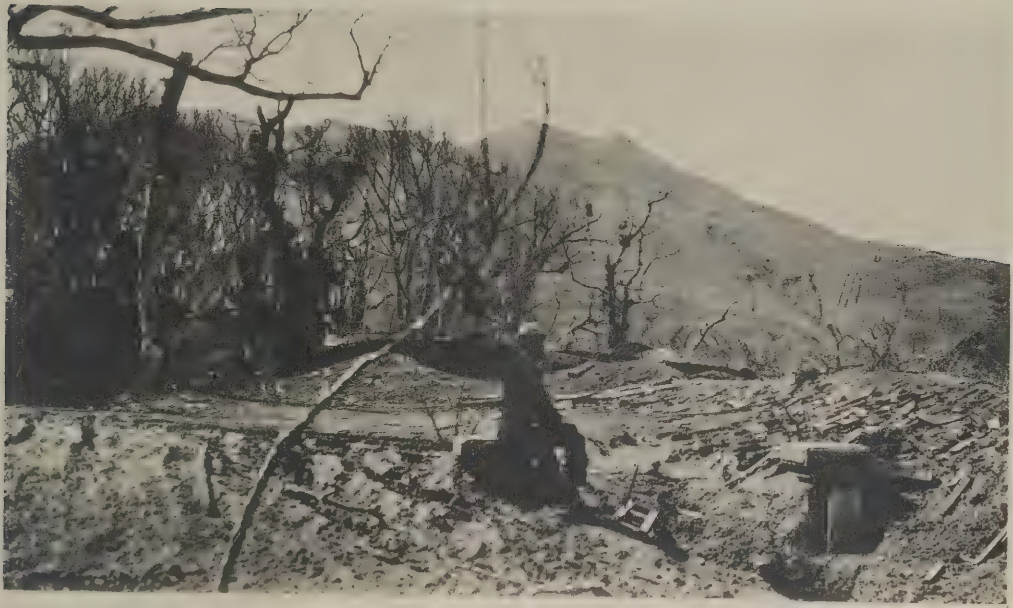

Fig. 60. Scene at Krokami, in the E. Part of Sakura-jima. The Gate Posts of the Miyabara Elementary School very nearly buried by Pumice and Ashes. (The man is sitting on one of the gate posts.)

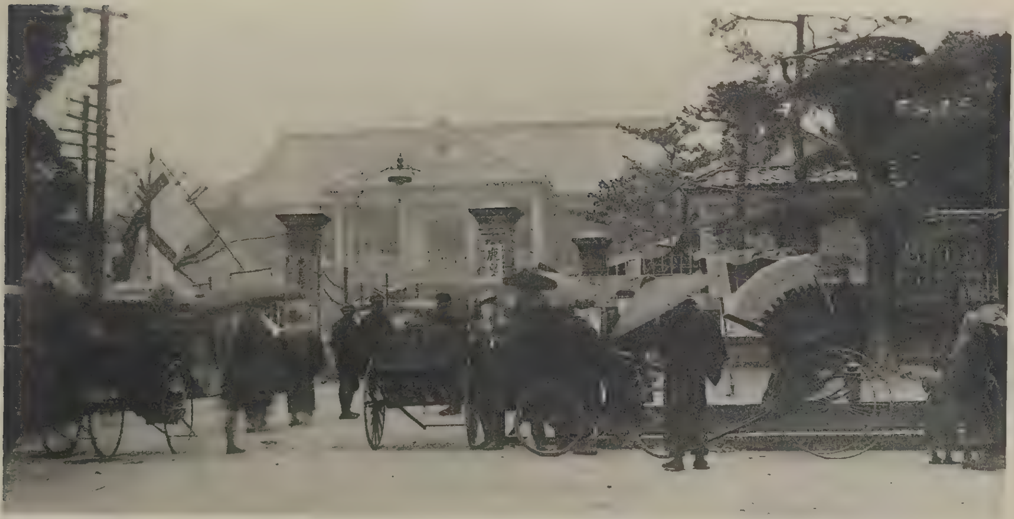

Fig. 61. Scene before the Prefectural Office, on the morning of Jan. 17th, 1914, when there was a slight ash-precipitation for the first time in the city of Kagoshima.

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Sakura-jima Eruption of 1914. (F. Omori, phot.)

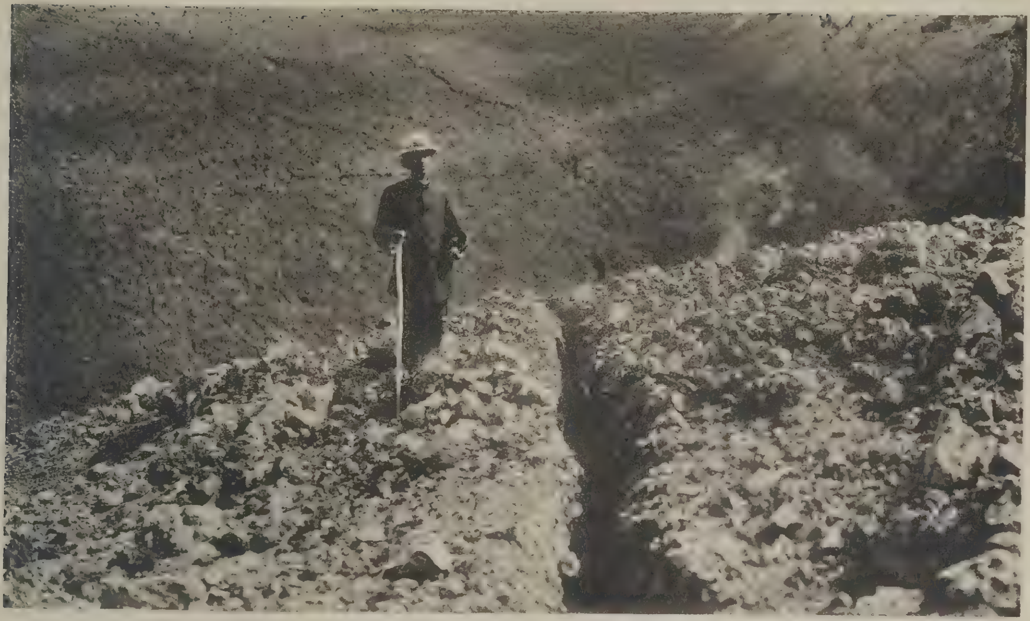

Fig. 62. **A Deep Crack (depth=5 m.),** formed across the layer of the new volcanic débris on the 460 m.-Hill, near the Lava Source on the West Side. (Oct. 1916.)

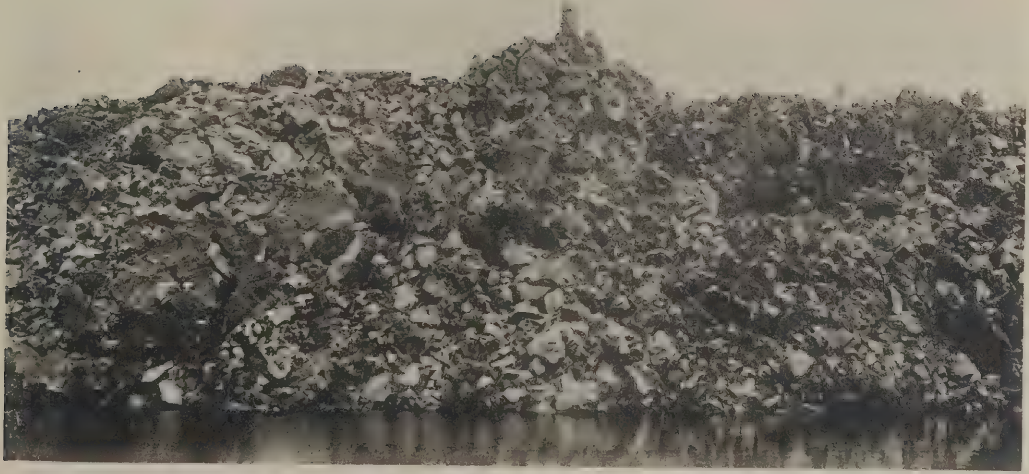

Fig. 63. **The New Lava Coast,** in the locality where the 102-metre Asahi-yama Hill had existed. (Oct. 1916.)

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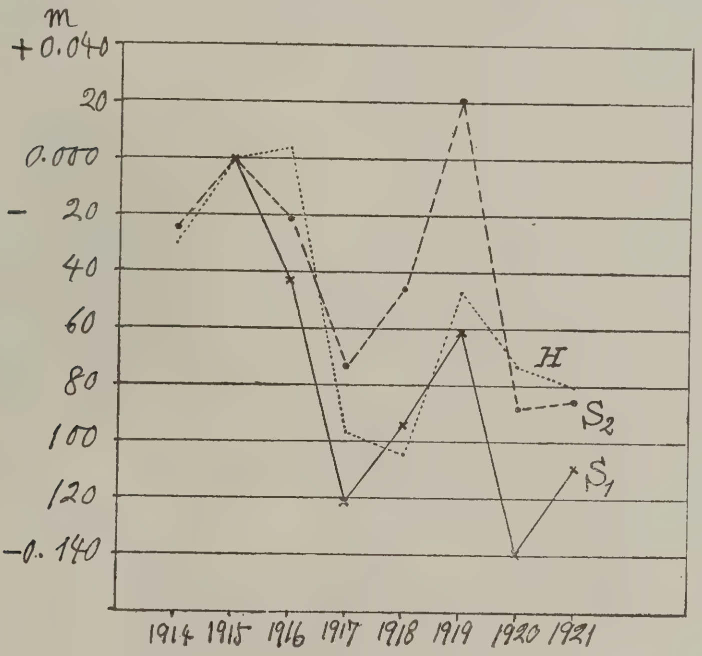
mark No. 2469 at Ogawa-machi (Kagoshima) was 0.407 metre lower just after the eruption, in June 1914, than in the year 1892, while the elevation of the ground during the 22 years between the latter date and the year of the eruption (1914) must have been some 0.15 metre, giving the resultant depression of ground of about 0.407 m+0.15 m=0.557 m. at the harbour.

Fig. 64. Variation of the Mean Annual Sea-leval Height, referred to 1915.



S_1 ......Mean Sea-level at Kagoshima.
S_2 ......Mean Annual Value of the High Tide Level at Kagoshima.
H ......Mean Sea-level at Hososhima.

24. Casualty and Loss of Property. The amount of mortality involved in the great volcanic eruption and the strong earthquake on Jan. 12, 1914, was amazingly small. The inhabitants of Sakura-jima were brought, by means of steamers, mortor-boats, and other craft, safely to the city of Kagoshima and other places on the coast of the provinces of Satsuma and Osumi, there having been only two cases of death and 27 cases of missing out of the whole island population of over 21,000. Of the 16 earthquake victims relating to the Kagoshima district, excluding Sakura-jima, about a dozen were killed at a place called Tenjin-ga-seto, 2½ km. to the s.w. of the city, by the fall of a cliff of loose formation on the road side where a group of the fugitives were resting.

Tables IX and X are the official statements of the different items of the damage caused by the volcanic and seismic convulsions. The amount of the loss of property was estimated at the time at a little less than 40 million yen, as follows :—

		yen
Kagoshima City		963,007
Kagoshima District		7,244,257
Ibski	,,	35,676
Hioki	,,	55,587
Izumi	,,	1,188
Isa	,,	22,924
Aira	,,	8,998,060
Soö	,,	14,751,904
Kimotski	,,	5,088,855
Total.		37,161,458

Damage to	Total.	Sakura-jima only.
	yen.	yen.
Cultivated Field, etc.	28,980,536	4,704,750
Road, Bridge, etc.	209,559	——
Dwelling Houses, etc.	2,258,188	1,072,287
Agriculture.	2,217,041	933,150
Sericulture.	318,251	——
Private Forest.	1,982,091	371,077
State Forest.	377,572	11,030
Live Stock.	754,487	80,126
Acquatic Product.	63,733	33,784
Sum.	37,161,458	7,206,204

Table IX. List of the Seismic and Volcanic Damage in Kagoshima Prefecture Caused by the Sakura-jima Outburst of 1914.

Seism. and Volcanic Damage.	City or District.	Kagoshima City.	Kagoshima District. (including Sakura-jima)	Ibski District.	Aira District.	Soö District.	Kimotski District.	SUM.
Casuality.	Killed.	13	18	—	—	—	4	35
	Wounded.	96	25	—	—	—	—	121
	Missing.	—	27	—	—	—	—	27
Domestic Animals killed.		—	2,875	—	—	1	9	2,885
Number of Dwelling Houses.	Burnt (volc. erupt.)	—	2,066	—	—	—	1	2,067
	Totally collapsed (eqke.)	29	28	1	10	—	45	113
	Half collapsed „	117	38	1	6	2	70	234
	Damaged „	9,405	1,222	1	1	4	915	11,548
	Buried under pumice and ashes.	—	59	—	—	9	1,568	1,636
Number of Other Buildings.	Burnt (volc. erupt.)	—	1,790	—	—	—	—	1,790
	Totally collapsed (eqke.)	94	62	2	45	—	46	249
	Partially collapsed „	182	28	1	15	2	99	327
	Damaged „	1,058	58	—	25	—	—	1,141
	Buried under pumice and ashes.	—	22	—	—	21	1,478	1,521
Roads.	Covered by ashes (Number of places).	—	14	4	105	48	28	199
	Do., total length, in *cho*.*	—	273	32	4,305	1,682	2,812	9,104
	Damaged (number of places).	20	70	—	—	—	—	90
	Do., total length, in *cho*.*	7.5	17	—	—	—	—	42.5
	Embankment broken down or damaged (number of places).	—	3	—	—	—	—	3
	Do. (total length).	—	198′	—	—	—	—	198′

---

* 1 *cho*=360 *shaku*=109 metres nearly.

Table IX. List of the Seismic and Volcanic Damage in Kagoshima Prefecture Caused by the Sakura-jima Outburst of 1914. (*Cont.*)

Seism. and Volcanic Damage.	City or District.	Kagoshima City.	Kagoshima District. (including Sakura-jima.)	Ibski District.	Aira District.	Soö District.	Kimotski District.	SUM.
Miscel-laneous Damage.	Bridges damaged.	10	4	—	3	—	—	17
	Old wooden water work pipes damaged.	43	—	—	—	—	—	43
	Ishigaki, damaged.	466	1,763	—	4	—	—	2,233
	Telegraph posts overthrown.	—	4	—	—	—	—	4
	Boats lost or damaged.	35	23	—	—	—	1	59
	Landslips.	10	32	4	10	—	2	58
Culti-vated Fields, Forest, etc., covered by ashes or buried under lava.	Paddy field covered by ashes.	*tan.* 1,825	*tan.* 5	—	*tan.* 59,301	*tan.* 46,381	*tan.* 51,788	*tan.** 159,300
	Field covered by ashes.	1,036	9,079	—	131,779	207,896	202,744	552,535
	Do. buried under lava.	—	7,432	—	—	—	—	7,432
	House ground, covered by shes.	4,162	916	—	18,437	15,317	14,001	52,833
	Do. buried under lava.	—	742	—	—	—	—	742
	Forest and waste land covered by ashes.	1,132	24,218	—	344,549	176,869	327,446	874,214
	Do. buried under lava.	—	4,398	—	—	—	—	4,398
	Miscellaneous grounds, covered by ashes.	205	20	—	1,876	31	1,434	3,566
	Do. buried under lava.	—	12,574	—	—	—	—	12,574

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* 1 *tan*=300 *tsubo*=10,667 sq. ft.=992 sq. m.

Table X. Seismic and Volcanic Damage in Sakura-jima and at the Opposite Coast of Osumi.

Seismic and Volcanic Damage. / Village.		Kagoshima District. (Sakura-jima).		Kimotski District.		SUM.
		Nishi-Sakura-jima-mra.	Higashi-Sakura-jima-mra.	Ushine-mra.	Mobiki-mra.	
Casualty.	Killed.	1	1	4	—	6
	Wounded.	9	—	—	—	9
	Missing.	4	23	—	—	27
Domestic Animals killed.		2,500	373	8	1	2,882
Number of the Dwelling Houses.	Burnt (volc. erupt.)	1,419	644	1	—	2,064
	Totally collapsed (eqke.)	21	3	35	10	69
	Partially collapsed „	16	10	20	50	96
	Damaged.	654	517	5	—	1,176
	Buried under ashes and pumice, or under lava.	9	50	759	628	1,446
Number of other Buildings.	Burnt (volc. erupt.)	1,260	530	—	—	1,790
	Totally collapsed (eqke.)	16	25	21	25	87
	Partially collapsed (eqke.)	17	5	19	80	121
	Damaged.	38	16	1	—	55
	Buried under ashes and pumice, or under lava.	10	12	699	610	1,331
Cultivated Fields, Forests, etc.	Buried under lava. (area.)	*cho.* 30	*cho.* 54	—	—	*cho.* 84
	Buried under ashes. (area.)	60	126	*cho* 726	*cho.* 720	1,632

CHAPTER IV. NOTES ON THE ANEI ISLETS.

25. Smaller Islets. The following notes relate to the Anei-jima,* or the group of the islets formed off the N. E. coast of the island of Sakura-jima after the great eruption of 1779, which I have visited on Oct. 21, 1916.

Inoko-jima (猪之子嶋). When seen at 7 A. M. at the time of a minimum tide very nearly, there was to be observed only a rock head 1 metre in diameter projecting 1 foot above the water. This disappeared under water at high tide times. About 120 feet apart there was another rock piece seen under the water surface.

Doro-jima (泥嶋). After the recent great eruption, this islet, once sufficiently large in dimension, became entirely submerged under water even at the lowest tides. At 7.50 A. M. (Oct. 21st), when the tide was lowest, a rocky prominence of the sunken islet was 6 feet deep, while another was 7 feet deep, the surrounding part being at the depth of 15 feet. On the submerged surface of the Doro-jima there were several rock blocks 6 feet or more in size, being similar to those scattered on the Moe-jima, probably precipitated from the neighbouring eruption vents in 1780.

Nakano-shima (中之嶋一名輕石嶋). The islet (fig. 67), also called Karuishi-jima (Pumice Islet), is almost entirely composed of spongy pumiceous materials of ashy or brownish colour, mixed occasionally with small compact lava pieces of light black colour. On the side facing the Iwo-jima, the beach about 80 feet in width, where pine trees had formerly grown, has been converted into a soft clayey bed with roots and broken trunks of dead trees, partly standing in water. At the time of my visit the height of the highest point (*A*, fig. 65) of the islet was about 22½ feet above sea level. The middle depression *B*, about 50 feet in diameter, is surrounded by large pumiceous fragments, 12 feet in maximum height, with some smaller blocks at centre. This may be the collapsed source of lava, or craterlet, being much similar to the Mar-yama (丸山) of the Omoe-zaki, aud the Kyono-tsuka (經之塚) of the Moe-zaki. The precipitation of the new ashes was about 1 foot in thickness. Some pine trees 0.2 or 0.3 foot in diameter were still growing on the islet. The depression since the recent eruption seems to have been about 6 feet.

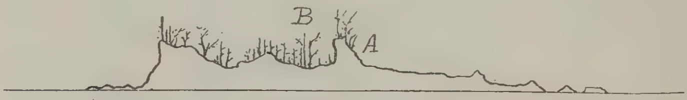

Fig. 65. Nakano-shima seen from Doro-jima.
A......Highest Rock.
B......Small Depression.

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* See the Bulletin, Vol. VIII, No. 2.

Iwo-jima, or Sulphur Islet (硫黃嶋). At the time of my visit, 9 A. M. (Oct. 21st), the islet (fig. 68), crescent in form and composed entirely of black solid lava blocks, had the maximum width of about 80 feet and the length above water of about 320 feet, the highest rock being 10 feet above sea-level. At a full tide time, the height of the islet would be reduced to only about 1 metre. At the inner, or concave, side of the islet there is a narrow deep vertical crack just covered by water, for the length of about 210 feet; the width was generally 2½ feet, and the depth varied mostly between 15.6 and 19.1 feet along the crack length. At one point, however, the depth reached an extraordinary great value of 43.1 feet.

The lava of Iwo-jima, which was formed by a submarine eruption from the centre situated probably on the concave side, is entirely different in nature from that of the new lava islets formed after the recent eruption, there being no special conchoidal, wavy, tubular, or filamental arrangement so characteristic of these latter. The Iwo-jima, which is higher toward the end facing the Moe-jima, is overgrown by reed, there being found only one dead pine tree 5″ in diameter.

26. Moe-jima (燃嶋) The islet* (fig. 66) is the largest of the Anei group and consists of the north and south plateaus separated by a narrow valley district, on which the habitations of 45 houses are situated. The plateaus, skirted by a narrow beach of maximum width of 120 feet, have steep sides, the north cliff reaching the height of 43.2 metres. The islet is mainly composed of whitish pumice lying on layers of soft clay which dip down towards the N. W., and which are well exposed at the S. E. and the S. bases of the south plateau. On the inner, or S. W., side of the latter there is no exposure of the clay. The surface layer, about 6 feet in thickness, is composed of ordinary pumice particles which was mainly the result of the submarine precipitation of the ash and pumice in the Sakura-jima eruption of 1779, prior to the upheaval of the Moe-jima; the ash precipitation on the occasion of the 1914 eruption being only about 1 foot thick. The underlying layer of white pumice, generally 7 or 8 feet in thickness, is thickly mixed with various dead shells; being abundant, amongst the others, smaller species of the oysters growing unfixed to the rocks, now extinct in the Kagoshima bay. (See figs. 69, *a* to *d*.) The shell-bearing layer, which is found throughout the islet and extends over tops of the two plateaus and the intervening depressed village portion, represents of course the sea bottom elevated at the time of the eruption of 1779, and the thick underlying portion of the white pumice layer free from the mixture of shells must be in the main the result of the precipitation of pumice during the previous eruptions of Sakura-jima, probably in 1468 to 1476. At the s. end of the islet the shell-bearing layer lies directly on the well developed strata of clay.

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* See the Bulletin, Vol. VIII, No. 2, Pl. XII, fig. 7.

Throughout the islet here and there are found large blocks of loose and well burnt lava placed on the pumiceous surface layer. These were probably projected in 1779 from some of the neighbouring eruptive vents prior to the elevation.

CHAPTER V. ON SUCCESSIVE OCCURRENCES OF EARTHQUAKES AND VOLCANIC ERUPTIONS.

27. Successive Occurrences of Earthquakes. The severe Kagoshima earthquake of Jan. 12th, at 6. 28 P. M., was preceded by a shock in the central part of the Inland Sea, which took place on the same day at 6. 12 P. M. (See Table XI.) These two earthquakes, whose time interval was only 16 minutes, may be regarded as being co-relative. The direct distance between the centres of the two earthquakes was 375 km. The Inland Sea earthquake, whose origin was situated near the Myojin islet (明神嶋), at $\varphi=34°\,8'$ N., $\lambda=133°\,13'$ E. was not destructive and had a small area of sensible motion, the maximum radius being 145 km. The major and minor diameters of the strong intensity area were about 56 and 37 km. respectively.

The following are examples of successive occurrences of destructive earthquakes from the Inland Sea and from some other part of Japan. (i). The earthquake on June 2nd, 1905, at 2. 39 P.M. caused some damage both on the Sanyo-do and the Shikoku coasts, namely, at Kure, Eda-jima, and Hiroshima, as well as at Mitsugahama, Gunchu and Matsuyama, resulting in the casualty of 188 persons and the total destruction of 64 houses. Simultaneously with this disturbance in the western part of the Inland Sea there took place numerous shocks at the island of O-shima (Izu) and the vicinity, which began on May 28th. Among these there were two strong earthquakes which occurred respectively on the 5th, at 1.45 A.M. and on the 7th, at 2.39 P.M. The second shock was semi-destructive and produced in the island of O-shima a partial collapse of three houses, and cracks and falling down of roads and stone fence walls at 674 places. The after-shocks continued till the 15th of the same month. (ii). Three among the group of the destructive

Anei Islets Group.

(F. Omori, phot.)

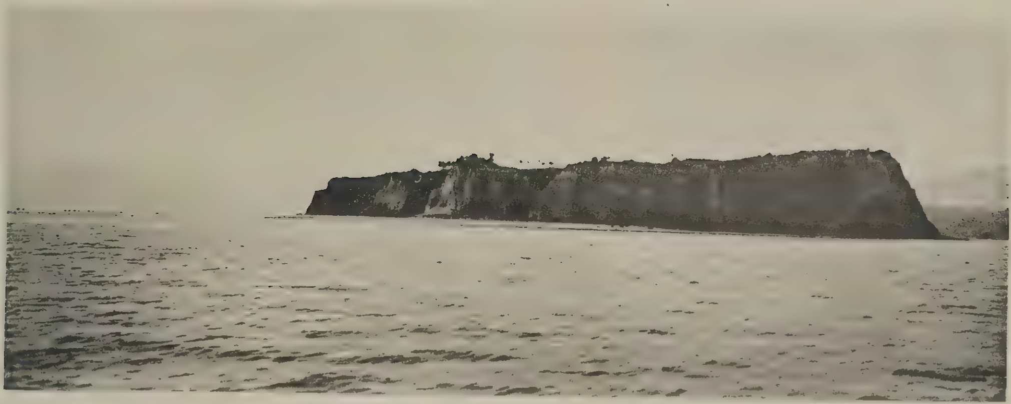

Fig. 66. Moe-jima seen from the East. (Oct. 1916.)

Fig. 67. Nakano-shima (Pumice Islet) seen from the Moe-jima. (Oct. 1916.)

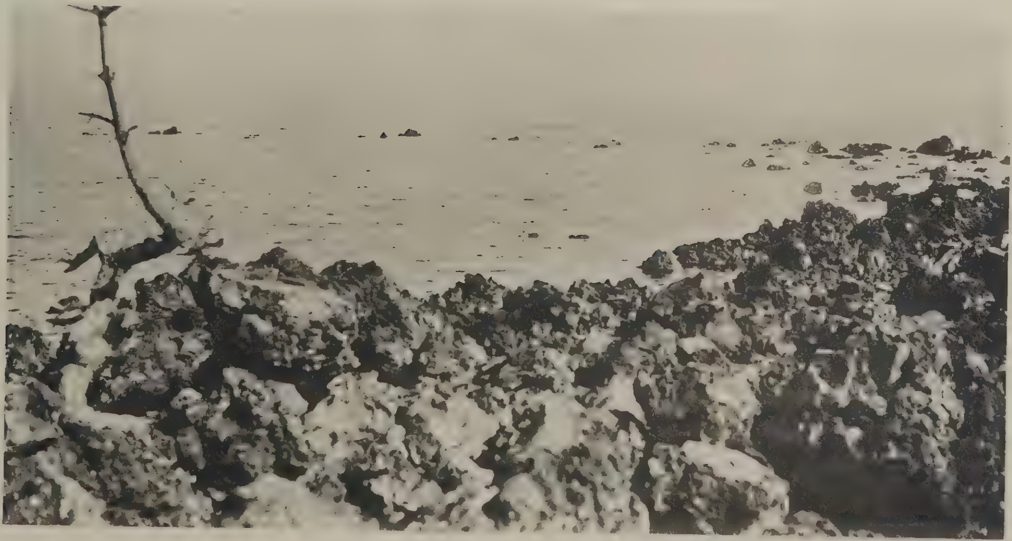

Fig. 68. Iwo-jima, showing the arc form. (Oct. 1916.)

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Moe-jima and Shell Layer.

(F. Omori, phot.)

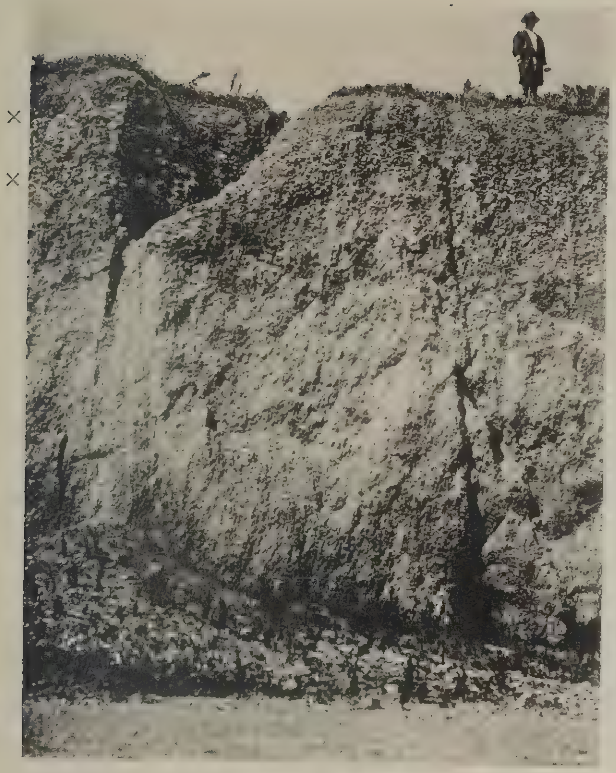


Fig. 69,a. View of the S. E. Cliff of the Islet, containing Shells in the Surface Layer (××).

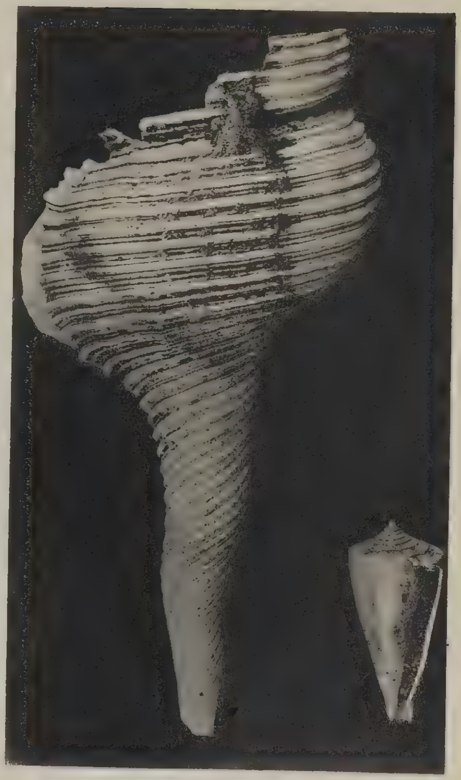


Fig. 69,c.

Fig. 69,b.

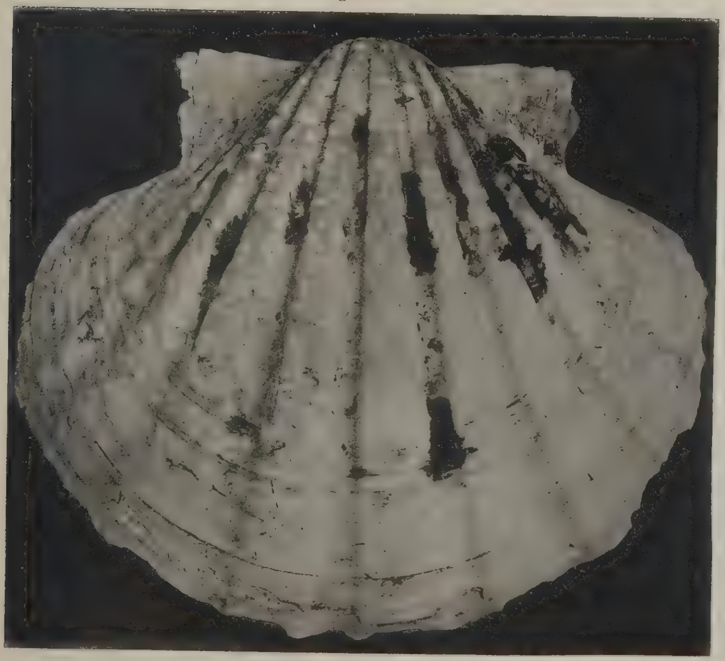
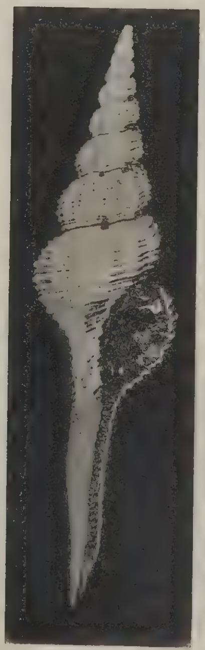


Fig. 69,d.



(**b**), (**c**), (**d**). Some of the Shells, in natural size.

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Sakura-jima.

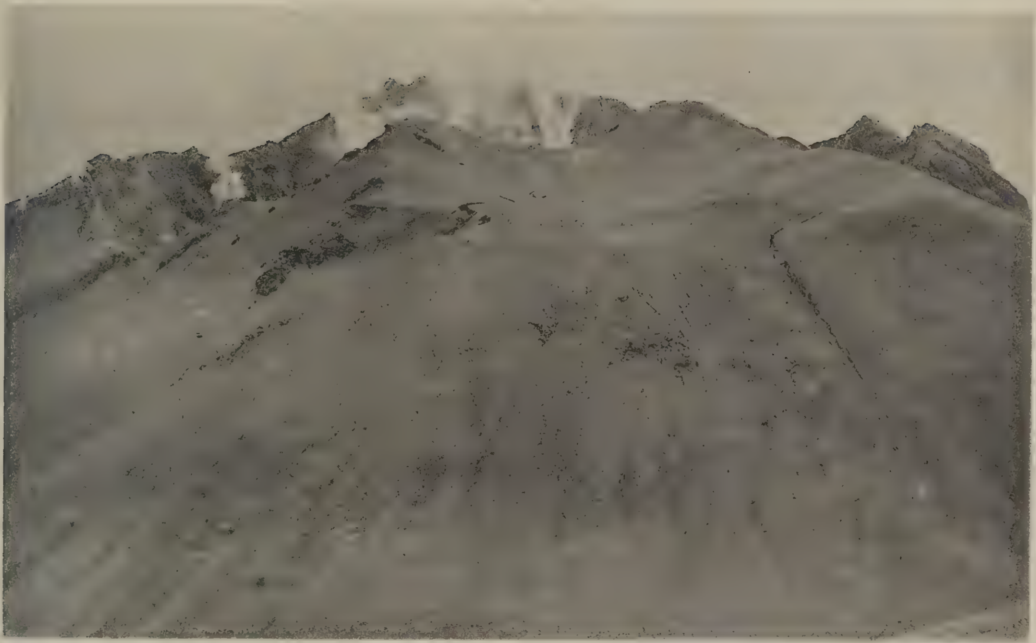

Fig. 70. Naka-dake Crater, seen from the Kita-dake; with the S. Cliff Wall of the Minami-dake shown on the back-ground. (Jan. 1915. M. Ueda, phot.)

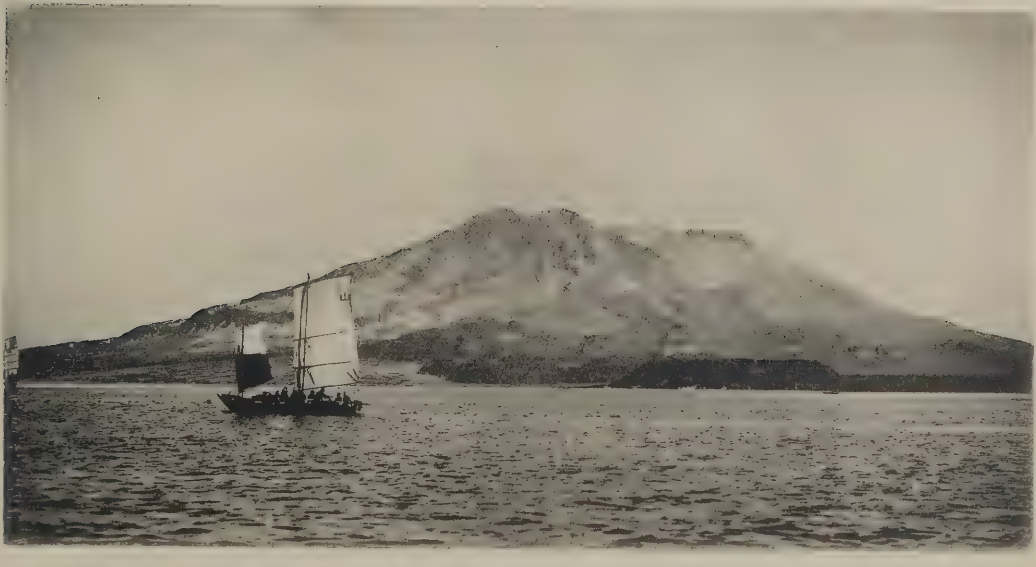

Fig. 71. Sakura-jima seen from the Kagoshima Channel, Oct. 1916. (F. Omori, phot.)

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Table XI Observation of the two Strong Earthquakes on Jan. 12, 1914.

Meteorological Observatory.	Time of Occurrence.	Intensity.	Remarks.
Inland Sea Earthquake.			
Shisaka-jima.	6 11 29 P.M.	Moderate.	Quick in nature, accompanied by sound.
Niihama.	6 11 58	"	Quick in nature, accompanied by sound. Houses shaken.
Tadotsu.	6 12 09	"	Quick in nature, with vert. motion.
Kure.	6 12 28	"	" "
Hiroshima.	6 12 25	"	
Kochi.	6 12 03	"	Doors shaken.
Besshi.	6 11 40	Slight.	Slow in nature, accompanied by sound. Doors shaken.
Matsuyama.	6 11 59	"	Quick in nature.
Okayama.	6 12 18	"	
Sakura-jima Earthquake.			
Kagoshima.	6 30 00 P.M.	Destructive.	Accompanied by sound.
Kmamoto.	6 28 55	Moderate.	Duration long.
Miyasaki.	6 29 20	"	Houses shaken.
Saga.	6 29 30	Strong.	Quick in nature.
Nagasaki.	6 29 27	Moderate.	Slow in nature.
Sasebo.	6 28 45	Slight.	
Fkuoka.	6 28 50	Unfelt.	
Nase (Oshima).	6 28 53	"	
Hiroshima.	6 30 05	"	Slow in nature.
Hamamatsu.	6 28 45	"	Quick in nature.
Osaka.	6 29 28	"	
Tokyo.	6 30 21	"	

earthquakes in the Ansei period furnish an interesting case of the successive westward transference of seismic activity. The great earthquake of Dec. 23, 1854, at 9 A.M., originated off the coast of Tokai-do. The next day, the 24th, at 5 P. M., there took place the equally great Nankai-do earthquake, the two seismic centres being separated by a mutual distance of 320 km. These sub-oceanic shocks were followed on the 26th, at 10 A.M., by a seismic disturbance at the western part of the Inland Sea, which caused damage at Osu and Yoshida, in Iyo, and at Oita and Kokra at the N. E. part of Kyushu. (iii). The famous violent earthquake on Sept. 4th, 1596, the first year of Keicho, which destroyed the magnificent castle buildings of Toyotomi Hideyoshi at Fushimi, near Kyoto, did not happen alone, but was preceded by the destructive shock of Oita and Beppu on the 1st of the same month, which originated in the bay of Beppu, at the extreme west of the Inland Sea. This latter earthquake, accompanied by *tsunami* (tidal waves), is well known on account of the submergence of the Uryu-jima, which had been a populous islet near the coast of Oita. (iv). The two severe earthquakes on Jan. 17 and April 30, 1897, which caused some damage about the town of Suzaka in the vicinity of the Asama-yama volcano, were each time preceded by a strong shock in the western portion of the Inland Sea, and followed by another off the southern Pacific coast of the Main Island, as shown next:

Date and Time of Occurrence.	Position of Eqke. Origin.	Major and Minor Diameters of the Area of Sensible Motion.
Jan. 17, 1897; 0.49 A.M.	Inland Sea (off the coast of Aki).	250 × 140 *ri*.*
„ „ „ 5.36 A.M.	Suzaka (Shinano.)	130 × 110 „
„ 18, „ 9.27 P.M.	Pacific Ocean (near Izu.)	120 × 90 „
April 19, 1897; 9.30 A.M.	Inland Sea (off the coast of Aki).	170 × 120 „
„ 30, „ 4.02 P.M.	Suzaka (Shinano).	130 × 90 „
„ 16, „ 0.14 A.M.	Pacific Ocean (off the coast of Totomi).	90 × 80 „

Examples like these seem to indicate the existence of the mutual connection between the seismic disturbances of the Inland Sea and those of other parts of Japan, volcanic or otherwise. (v). As a further example, may be mentioned the Inland Sea earthquake on March 17, 1649, which was felt strongly in Iyo and Aki, and damaged the *ishigaki* (stone retaining walls) of the three castles of Uwajima, Matsuyama, and Hiroshima. This was preceded and followed by destructive shocks of local nature in the Kwanto provinces of Musashi, Sagami, and Shimotsuke, as follows: (1). June 16, 1647. The two provinces of Musashi and Sagami were strongly shaken. Damage was done to the *ishigaki* of the Yedo castle and the mansions of the daimyos. The head of the bronze Daibutsu (huge image of Buddha) at Ueno was thrown down. The ferry landing of the Banyu-gawa was also damaged. (2) June 12, 1648. A strong shock took place in the vicinity of Hakone-yama, causing damage to the mountain paths. (3). July 29, 1649. The earthquake was strongly felt in Musashi and neighbouring provinces, damaging the *ishigaki* of the Yedo castle, and overthrowing the residences of several daimyos. The head of the Daibutsu at Ueno was again thrown down. At Nikko, the stone fence of the Toshogu shrine was thrown down at several places. (4). Sept. 1, 1649. The shock was felt strongly in Musashi, causing some damage to the Hirakawa gate of the castle of Yedo. At Kawasaki 100 dwelling houses were destroyed. In the year 1649 the Shirane-san (Nikko), the Asama-yama, and the Aso-san were in eruption. Among these four Kwanto earthquakes, (2) and (3) seem to have been of volcanic origin. So was also the case with the Kagoshima earthquake of Jan. 12, 1914, and the Oshima earthquake of (i), and the two Suzuka earthquakes of (iv), and possibly also the Beppu earthquake of (iii).

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* 1 *ri*=3.927 km.

28. Volcanic Eruption and great Tectonic Earthquake. In connection with the destructive Sakura-jima earthquake at 6. 28 P. M., on Jan. 12, 1914, I may mention the great Kisagata earthquake on July 10, 1804, (文化元年六月四日象潟大地震), when the ground was elevated some 3 metres for the length of over 10 miles along the coast of the Japan Sea, at the foot of the Chokai volcano. It was on this occassion that the lake of Kisagata, formerly famous for its beautiful scenery and known as the Matsushima of Dewa (Provinces of Uzen and Ugo), was uplifted and dried, so that its numerous islets crowned with pine trees are at the present day left amid the converted cultivated fields. It is scarcely to be doubted that the Kisagata earthquake was connected with the great eruption in 1801 of the Chokai-san which resulted in the formation of the new lava dome called the Kyowa-dake (享和岳), the present central and highest peak of the volcano. The last great explosive eruption of Mount Fuji on Dec. 16, 1707, (寶永四年十一月廿三日), which resulted in the formation of a new large cinder mound "Hoei-san;" may also be supposed to have been connected with the earthquake on Oct. 28, of the same year, (寶永四年十月四日), which is regarded to be the greatest among the earthquakes experienced in Japan since the earliest historical times, and whose destructive motion area stretched from the northern part of Kyushu to the central part of Suruga in Tokaido. Again, the earthquake on Aug. 23, 1856, (安政三年七月廿三日), which was felt strongly along the S. E. coast of Hokkaido and produced tidal waves (*tsunami*) at Hakodate and along the coast of Yufuts (Tomakomai), was followed 28 days later, on Sept. 20 of the same year, by a great eruption of the Komaga-take volcano, situated on the southern border of the Volcano Bay. It is to be noted that the eruptions of Chokai-san, Komaga-take, and Fuji-san here mentioned were all markedly strong disturbances which continued for several days or several weeks. The destructive earthquakes which followed or preceded these volcanic outbursts may be regarded, together with the Sakura-jima earthquake on Jan. 12, 1914, as furnishing examples of non-local tectonic seismic disturbances connected with great volcanic manifestations. That such should be the case is easy to understand, as some of the volcanoes at considerable mutual distances, notably the Sakura-jima, the O-shima (Izu) and the Asama in 1777–1783 and again in 1909–1914, made eruptions successively in the course of a short time interval; it being thus evident that the volcanic stress is wide-reaching and affects simultaneously the whole island arc of Japan. This condition may of course lead, or may be precursory, to the occurrences of earthquakes of large extension. On the other hand, it is quite conceivable that the volcanic eruptions tend to relieve the stress accumulation within the earth's crust in the neighbouring area, thereby preventing the occurrence, or reducing the frequency, of seismic disturbances. Thus, the relation of volcanic and seismic phenomena may be summarized, as follows: Volcanic earthquakes, or those having origin under or near an active, dormant, or dead volcano, are usually limited in area and of no great intensity, belonging to the category of what may be termed a small local destructive shock;* in some rare cases, however, the eruptions are connected with large tectonic earthquakes.

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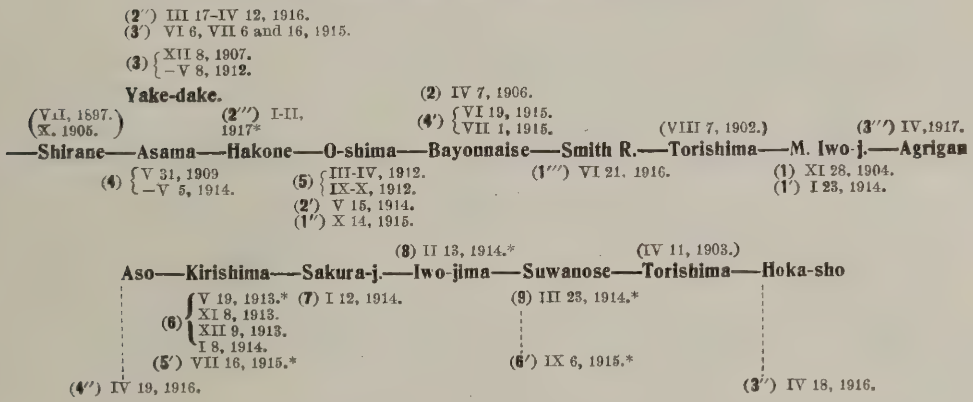
* An earthquake whose intensity is not enough to destroy ordinary wooden Japanese houses.

29. Successive Occurrences of Volcanic Eruptions. The occurrence in the recent years of the eruptions from the different mountains unmistakably indicates the existence of a close relation between the Fuji and Kyushu volcanic chains, as is illustrated below.

SCHEMATIC ILLUSTRATION OF THE SUCCESSIVE OCCURRENCES OF THE ERUPTIONS.


(2′′) III 17–IV 12, 1916.
(3′) VI 6, VII 6 and 16, 1915.
(3) XII 8, 1907. –V 8, 1912.
Yake-dake.
(VII, 1897. X. 1905.)
(2′′′) I-II, 1917*
(2) IV 7, 1906.
(4′) VI 19, 1915. VII 1, 1915.
(VIII 7, 1902.)
(3′′) IV, 1917.
—Shirane—Asama—Hakone—O-shima—Bayonnaise—Smith R.—Torishima—M. Iwo-j.—Agrigan
(4) V 31, 1909 –V 5, 1914.
(5) III-IV, 1912. IX-X, 1912.
(2′) V 15, 1914.
(1′′) X 14, 1915.
(1′′′) VI 21, 1916.
(1) XI 28, 1904.
(1′) I 23, 1914.
(8) II 13, 1914.*
(IV 11, 1903.)
Aso—Kirishima—Sakura-j.—Iwo-jima—Suwanose—Torishima—Hoka-sho
(6) V 19, 1913.* XI 8, 1913. XII 9, 1913. I 8, 1914.
(7) I 12, 1914.
(9) III 23, 1914.*
(5′) VII 16, 1915.*
(6′) IX 6, 1915.*
(4′′) IV 19, 1916.
(3′′) IV 18, 1916.

The series of the eruptions were repeated in four periods, or cycles, of successively decreasing intensity, as follows :—

(i) 1904 to 1914 : M. Iwo-jima (South Sulphur Island ;) Bayonnaise Rocks ; Yake-dake ; Asama ; O-shima ; Kirishima ; Sakura-jima ; Iwo-jima ; and Suwanose-jima.

(ii) 1914 to 1915 : M. Iwo-jima ; O-shima ; Yake-dake ; Bayonnaise Rocks ; Kirishima (eqkes. only) ; Suwanose-jima (eqke. only).

(iii) 1915 to 1916 :—O-shima ; Yake-dake ; Hoka-sho (near Formosa).

(iv) 1916–1917 :—Smith Rocks ; Hakone (eqkes. only).

1*st Period.* (1), the disturbance began near the south extremity of the Fuji volcanic chain, on Nov. 28, 1904, with the submarine eruption off the N. E. coast of Minami Iwo-jima of the Volcano Islands group, resulting in the production of an ephemeral islet. (2), On April 7, 1906, there followed a submarine eruption near the Bayonnaise Rocks situated 110 km. to the south of the Hachijo-jima. (3), then took place on and after Dec. 8, 1907, outbursts from the Yake-dake volcano in the Japan Alps, near the northern extremity of the Fuji chain. (4), there soon followed the activity of the Asama whose premonitory sign occurred in the form of a violent local earthquake on May 26, 1908, resulting in the strong explosions first on May 31 and Dec. 7 of 1909. The explosive violence of the Asama was greatest during 1912 and in the summer of 1913. (5), in the mean while, the O-shima was also thrown into an unusual activity and made splendid firework-like outbursts of lava in March-April and in Sept.-October, 1912. Toward the end of 1913, the three great volcanoes of the Fuji chain, namely, Asama, Yake-dake, and O-shima, passed the climax of their activity and were all brought to a state of rest. This meant the removal of the seat of volcanic activity to Kyushu. (6), initiated by the occurrence since May 19, 1913, of a group of local earthquakes in the neighbourhood of the Kirishima volcano, which had been dormant for the 10 years since 1904. The disturbance in the stress equilibrium of the earth's crust soon spread to the peninsula of Satsuma, and the town of Ijuin and the vicinity were shaken at the end of June of the same year by a severe earthquake and numerous secondary shocks. On Nov. 8 and Dec. 9 the Kirishima finally broke out into strong explosions. Thence the seismic and volcanic activity in the southern part of Kyushu underwent a rapid development, and the 3rd explosion of the Kirishima on Jan. 8, 1914, was followed, (7), 2 days later by the occurrence since the night of the 10th of the local earthquakes at Sakura-jima whose frequency rapidly increased; no less than 337 shocks having been registered even in the city of Kagoshima by means of an ordinary seismograph at the meteorological observatory during the 27 hours between the 11th, 3 A.M. and the 12th, 6 A.M. The great eruption of Sakura-jima finally began on the same morning at 10 o'clock. (8), after the Sakura-jima outburst, the telluric disturbance spread further southwards, resulting in the strong earthquake on Feb. 13 at Iwo-jima, one of the Satsuma islands group. (9), there was also a strong earthquake on March 23 at the Suwanose-jima situated further south.

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* Earthquakes only.

2nd Period. After the Sakura-jima eruption of Jan. 12, 1914, the volcanic activity reverted at once to the Fuji chain and, (1′), it was only one week later that the Minami Iwo-jima became again the scene of disturbance; a submarine eruption occurring at the same spot as in 1894 and resulting likewise in the formation of an ephemeral island. (2′), the O-shima made a third marked lava eruption on May 15. (3′), the Yake-dake quickly followed in the series and made an explosion on June 6, 1915. (4′), On June 19 and July 1 of the same year submarine eruptions took place from the vicinity of the Bayonnaise Rocks. Thereupon the volcanic activity was again transferred to Kyushu, and there followed, (5′), a strong earthquake on July 16 in the vicinity of Kirishima, and, (6′), another on Sept. 6 at the Swanose-jima.

3rd Period. The telluric disturbance went back to the Fuji volcanic chain for the 3rd time, and resulted, (1″), in the small outburst (smoke emission) of O-shima on Oct. 10–31, 1915. (2″), the Yake-dake made small explosions on March 17 and April 12, 1916. Then there followed slight disturbances in Kyushu: (3″), the submarine eruption on April 18, 1916, near the islet of Hoka-sho (vicinity of Formosa), and, (4″), a small eruption of the Aso-san on the next day, the 19th.

4th Period. The 4th stage of activity along the Fuji volcanic chain consisted of, (1‴), the submarine smoke emission in the vicinity of the Smith Rocks on June 21, 1916; (2‴), the local earth-sounds (*jinari*) and earthquakes of the Hakone in Jan. and Feb. 1917; and, (3‴), an eruption in April 1917 of the Agrigan island in the Marianas.

Of the four cycles of the volcanic activity above described, the 1st was the most powerful. The 2nd cycle was much weaker, while the 3rd and the 4th were very feeble.

30. Concluding Remarks. Through the liberality of the Imperial Earthquake Investigation Committee the present author was enabled to visit Sakura-jima several times during the course of, and after, the recent eruption, carrying on, amongst the others, tromometer observations of the after-eruptions and volcanic earthquakes. The eruption in question was, as far as the amount of lava outflow and ash precipitation is concerned, the greatest which happened in Japan during her historical times. This circumstance, coupled with the small size of the island volcano, caused a marked subsidence of the adjacent ground, especially of the bottom of the sea lying behind it, or to its north. Thanks to the kindness of the authorities of the Military Survey and the Hydrographic Office, laborious series of the precise leveling and soundings were carried on in the areas concerned, determining exactly the amounts of the displacements of the ground due to the great eruption and of the subsequent recovery.

The Sakura-jima outburst in conjunction with the Usu-san eruption of 1910 gives much light on the process of formation of *volcanic lake*, situated behind a volcano, and also the building up of the volcanic chains actually going on at present. The foregoing pages constitute a modest geometrical and seismological reports on the great Sakura-jima eruption of 1914, and the course of the after-events followed for the next 8 years.*

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* For an excellent petrological and geological study of the eruption the reader is referred to Professor B. Koto's paper, "the Great Eruption of Sakura-jima in 1914," published in Jour. Coll. Sc., Tokyo Imp. University, **38**, Art. 3, (1916).

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